Demoboard Exercises

MA 2067

User Manual

Version 1.0, Code No. 20 750 236

METREL®

1. Conductor continuity measurement

Background of measurement

Automatic trip out of mains voltage in case of present hazardous contact voltage is one of the most common protection methods used on electric mains installations. The disconnection device installed for this purpose must trip out or blow. But, one of basic requirements at this type of protection is low impedance connection of accessible metal parts to grounding system.

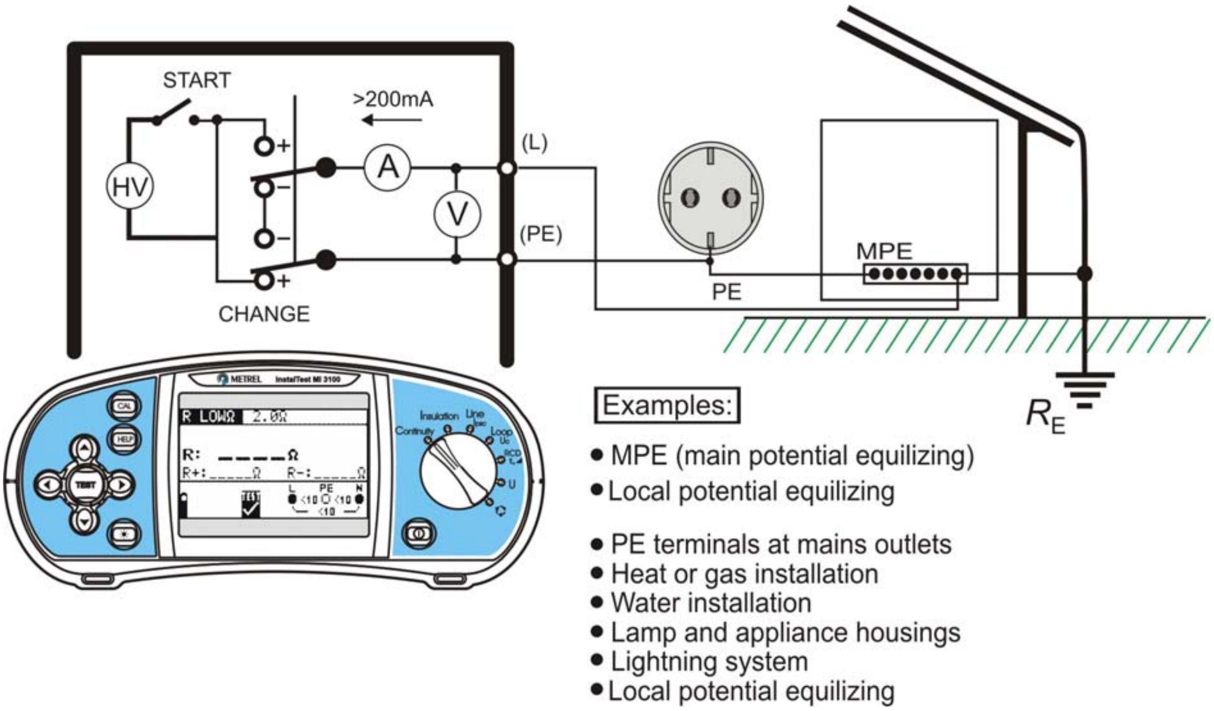
Measurements of continuity are carried out when testing connections between electric conductors, protection earth conductors and appliances, protection earth conductors and grounding system etc.
Resistance between two metal parts, which are connected together by potential equalizing conductor, must be:

$$R \leq \frac{50}{I_a}$$

R .... Resistance between two accessible metal parts connected together using additional potential equalizing conductor.
50...... Conventional touch voltage limit (50 V).
I_a .... Current, which assures tripping out protection device namely:
$I_a = I_{\Delta N}$ .... for residual current protection devices (RCDs),
$I_a = I_n$ .... nominal working current of overcurrent protections (fuses)

In case of RCD protection devices, I_a is equal to nominal differential current, while in case of overcurrent protection devices (fuses), I_a is the current, which causes melting and thus blowing of involved fuse within 5 s (the current is to be found in appropriate table for a certain type of fuse). At automatic installation fuses, I_a is the current, which ensures reliable tripping out involved automatic fuse (at B type of automatic installation fuses I_a is equal to 5 x I_n , at C type I_a is equal to 10 x I_n etc.).

Exercise No.1-1: Conductor continuity measurement - general



Measuring procedure
- Set *CONTINUITY* function.
- Set *LOWΩ 200mA* subfunction.
- Set test parameters and limits.
- Calibrate test leads if necessary.
- Connect item under test.
- After pressing START key, the test current flows through the object under test. The instrument measures voltage drop and test current and calculates resistance R_+.
- Polarity of test current is automatically exchanged, the instrument measures voltage drop and test current and calculates R_-.
- Final result is the average value of R_+ and R_-.

Notes
- **During the measurement, mains voltage must be switched off!**
- **Resistance of measuring leads must be compensated before test.**
- ***CONTINUITY 7 mA* is intended for fast continuity checks. This test is does not conform to regulatives!**

Documentation
The continuity test is one of the standard tests for verification of electrical installations. For measurements at a certain test object, final test report is to be done, containing all parameters of the measurements like type of the measurement, type and serial number of the test instrument, test place, operator of the test instrument etc. Measurement results must be placed into appropriate columns of the final test report.

Regulations

Requirements for continuity measurements are defined in IEC/EN 61557-4.
General requirements for equipment for testing safety of electrical installation are defined in IEC/EN 61557-1.

Exercise No.1-1: Conductor continuity measurement – Demoboard MI 2067

Simulation of faults with demoboard

Demonstration board enables to set eight different faults concerning low ohm connections, which can be freely combined enabling the user of the board to set a large number of fault combinations. Setting switches S4 to S11 to "fault" position, unacceptably high resistance is included into the tested loop (resistance R < 1 Ω in all loops in case switches are not in fault position).
The following high resistances (over limit) can be activated:

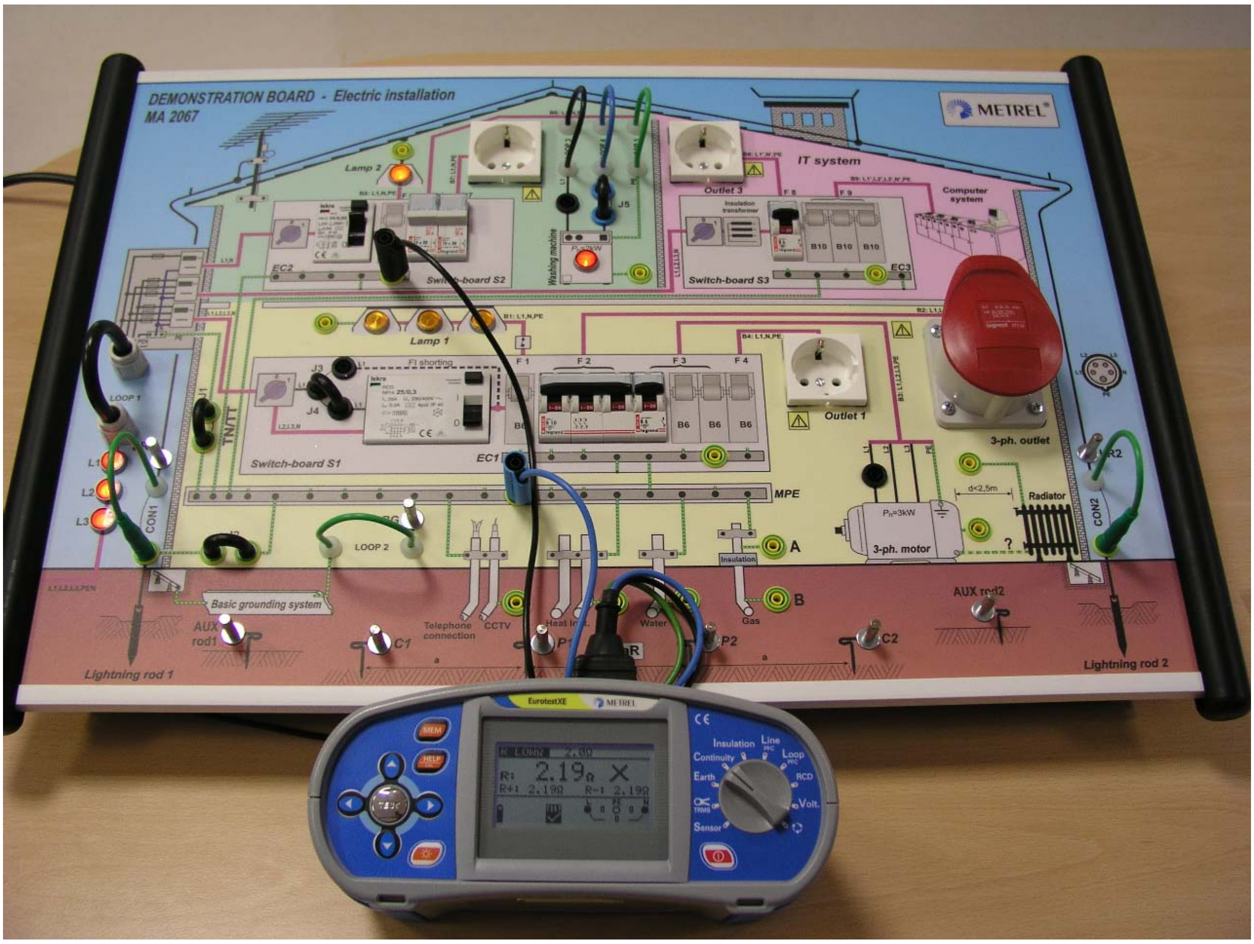
- S11: Main Potential Equalizing Collector (MPE) - Heat installation,
- S10: MPE - Gas installation,
- S9: MPE - Protection Earth Collector 2 (EC2),
- S8: Protection Earth Collector 1 (EC1) - PE terminal at three phase outlet,
- S7: EC1 - Casing of LAMP 1,
- S6: EC1 - Casing of 3 phase motor,
- S5: EC2 - Casing of LAMP 2,
- S4: EC3 - Accessible metal parts of computer system.

Example with demoboard

Example on figure below shows measurement of continuity between main potential equalizer MPE and local protection earthing collector EC2.

Demobard setup

Demoboard setup	*Condition*	*Notes*
S9 OFF	Continuity MPE – EC2 < 0.4 Ω	normal
S9 ON	Continuity MPE – EC2 >2.0 Ω	fault
Other settings		


DEMONSTRATION BOARD - Electric installation
MA 2067
METREL
IT system
Lamp 2
Lamp 1
Switch-board S2
Switch-board S3
Switch-board S1
Outlet 3
Outlet 1
3-ph. outlet
3-ph. motor
Radiator
Basic grounding system
Lightning rod 1
Lightning rod 2
LOOP 1
LOOP 2
MPE
EurotestXE

2. Insulation resistance measurement

Background of measurement
Appropriate Insulation Resistance between live parts and accessible conductive parts is a basic safety parameter that protects against direct or indirect contact of the human body with mains voltage.

Insulation resistance between live parts, which prevents short circuits or leakage currents, is also important. High fault (leakage) currents can cause fire, especially if they spark.

In general insulation decreases with age, dirty, moisture etc.

On electrical installations insulation resistance shall be measured between
- Phase conductors
- Phase and PE conductors
- Phase and neutral conductors
- Neutral and PE conductors

On electrical appliances insulation resistance shall be measured between
- Phase (connected together) and PE conductors
- Phase (connected together) and accessible conductive parts

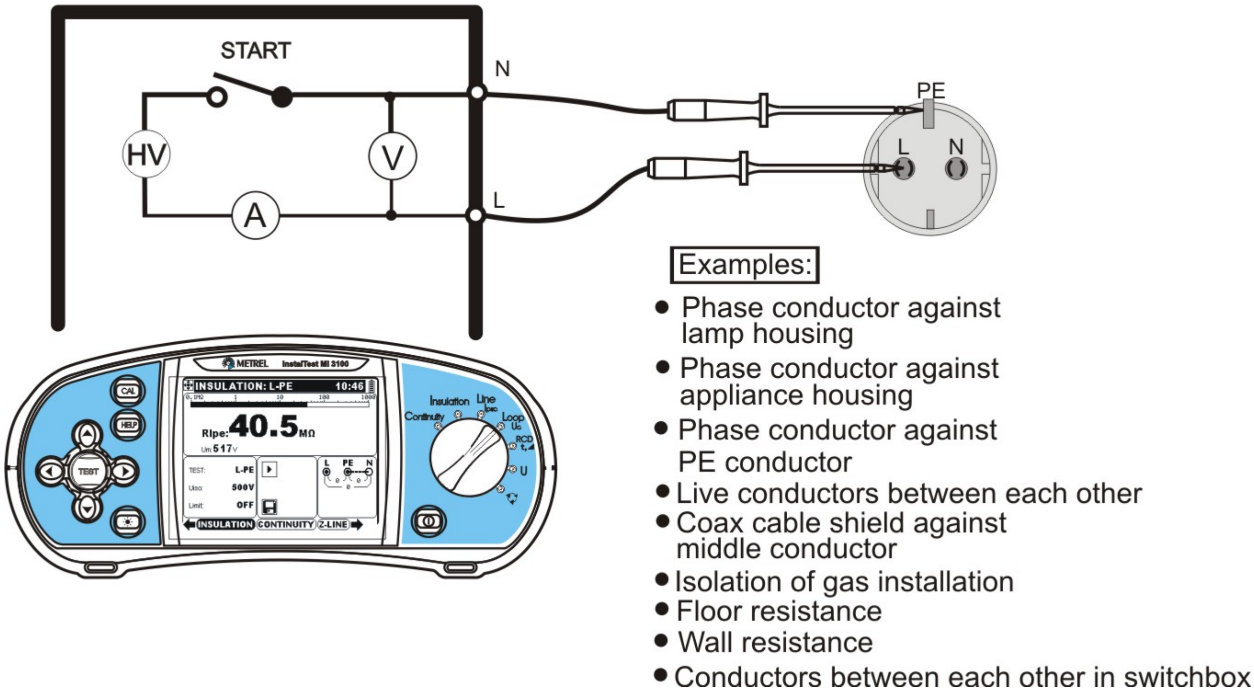
Typical measurement voltages and minimal allowed insulation resistances:

100 V...........0.100 MΩ	Telecommunication installations
250 V...........0.250 MΩ	Extra low voltage electric installations
500 V........... 0.500 MΩ	Low voltage electric installations (U_N<500 V), floor and wall resistances, insulation resistances of switch boards etc. Electrical equipment and accessories
1000 V ....1.000 MΩ	Low voltage electric installations (U_N>500 V), floor and wall resistances, insulation resistances of switch boards etc.

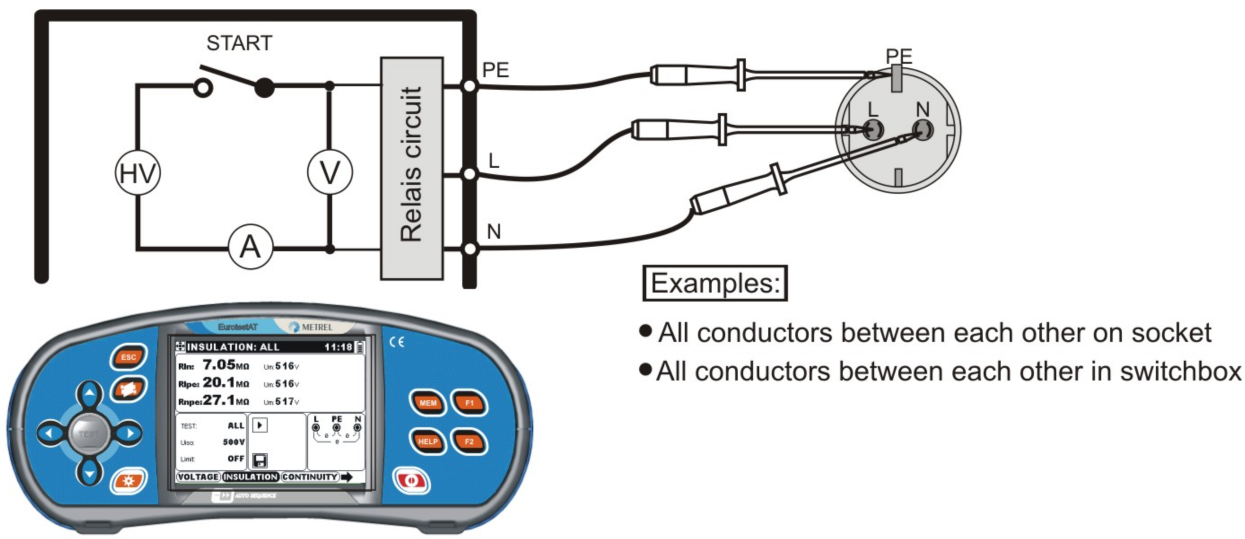
Exercise No.2-1: Insulation resistance measurement - general

Measuring connection

EXAMPLE 1
Standard measuring connection.



EXAMPLE 2
Some METREL instruments can perform the insulation tests L-PE, N-PE, L-N test in one step



Measuring procedure

- Set *INSULATION* function.
- Set *INSULATION* subfunction (LPE, LN, NPE, ALL, some models)
- Set test parameters (test voltage) and limit.
- Connect item under test.
- After pressing START key, test voltage is applied to test leads and thus to the object under test. The instrument calculates the value of insulation resistance on base of measured voltage and current.
- At the end of test the tested items is discharged.

Notes

- Mains voltage must be switched off during the test. Other fuses and switches should be closed to include all for safety relevant parts.
- If electrical loads (lamps, equipment) are connected to the mains the installation test between L and N terminal can usually not be carried out. This must be considered!
- Tested items must be discharged after the test with high voltage DC voltage. The measuring instruments do this automatically.

Documentation

The insulation test is one of the standard tests for verification of electrical installations.
For measurements at a certain test object, final test report is to be done, containing all parameters of the measurements like type of the measurement, type and serial number of the test instrument, test place, operator etc. Measurement results must be placed into appropriate columns of the final test report.

Regulations

Requirements for insulation resistance measurements are defined in IEC/EN61557-2.
General requirements for equipment for testing safety of electrical installation are defined in IEC/EN 61557-1.

Exercise No.2-1: Insulation resistance measurement – Demoboard MI 2067

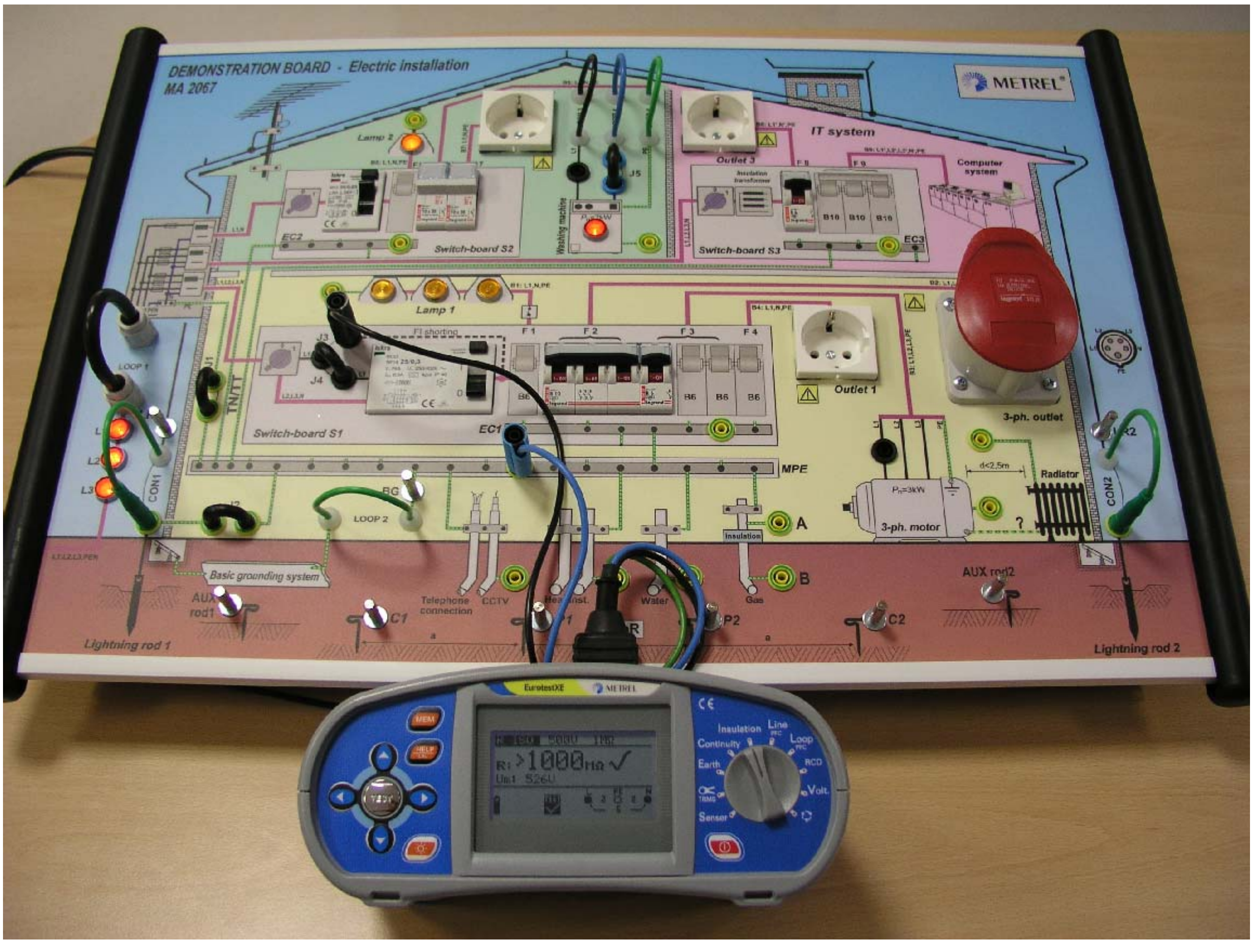
Demonstration board enables to set seven different faults concerning insulation resistance, which can be freely combined enabling the user of the board to set a large number of fault combinations. Setting switches S16 to S22 to “fault” position, unacceptably low insulation resistance are simulated:

S16: Outlet 3 (switch board S3): phase conductor L1 - neutral conductor N.
S17: Outlet 3 (switch board S3): phase conductor L1 - protection earth conductor PE.
S18: Washing machine: phase conductor L1 - floor (via metal housing).
S19: Washing machine: phase conductor L1 - protection earth conductor PE.
S20: 3 - phase motor: phase conductor L1 - protection earth conductor PE.
S21: 3 - phase outlet: phase conductor L2 - neutral conductor N.
S22: 3 - phase outlet: phase conductor L1 - phase conductor L2.

Example with demoboard
Example on figure below shows insulation resistance test between phase conductor and main potential equalizer MPE in switch board S1.

Demobard setup

Demoboard setup	*Condition*	*Notes*
S20 OFF	Insulation L1 – PE > 500 MΩ	normal condition
S20 OFF	Insulation L1 – PE < 0.5 MΩ	Fault on motor in L1
RCD 300mA OFF Jumper4 ON		to disconnect mains
Fuses 1 to 4 ON		to include complete wiring



3. Earth resistance measurements

Background of measurement
Correct earthing of accessible metal parts and PE conductors is one of the most important requirements when protecting electric installations. Well earthing will result in automatic trip out of mains voltage in case of a fault. Maximal allowed earth resistances depend on type of earthing (working earthing, protection earthing or lightning earthing) and installation (TN, TT). Earthing is also necessary measure when protecting electric installations against overvoltages.
There are different earth resistance measurement methods that can be carried out using two-, thre, and four-wire and/or with current clamp(s).

Two-wire test system is used in case there is no place to drive auxiliary test rods (is used in place without aux. test rods driving possibility) and a well grounded auxiliary terminal is available. When measuring earth resistance in TT system of installation, the power transformer's working earthing neutral conductor N can be used as one. The method is applicable also when measuring earth resistance on open connection of parallel lightning system at bigger buildings.

Three-wire test system is the only choice if measuring earthing resistance and there is no well earthed auxiliary terminal available. The measurement is performed with two earthing probes.

Four-wire test system is similar to the three wire one. Its advantage is that it is not influenced by the contact resistance between measuring terminal and tested item.

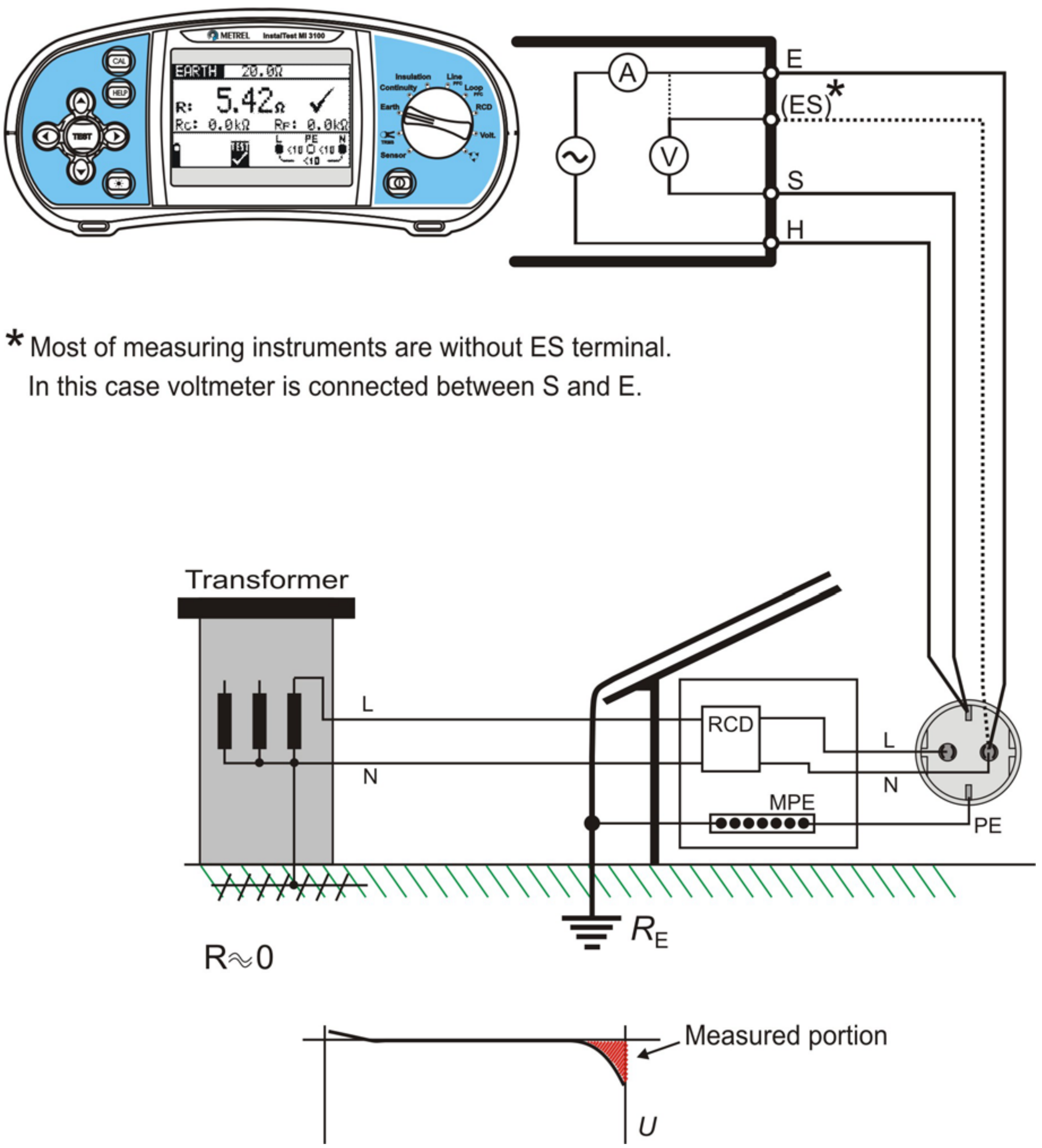
Current clamp test system is suitable when measuring earth resistances of individual earthing rods in an earthing system. The earthing rods do not need to be disconnected.

Two current clamp test system is used when measuring earth resistances of grounding rods, cables etc, under- earth connections etc. It is especially suitable in urban area.

Exercise No. 3-1: Earth resistance measurement (two wire method) - general

Measuring connection

EXAMPLE1
In this example the N conductor is is used as the auxiliary test terminal. The earthing resistance of the transformer and resistance of N conductor must be small compared to the measured resistance.



* Most of measuring instruments are without ES terminal.
In this case voltmeter is connected between S and E.

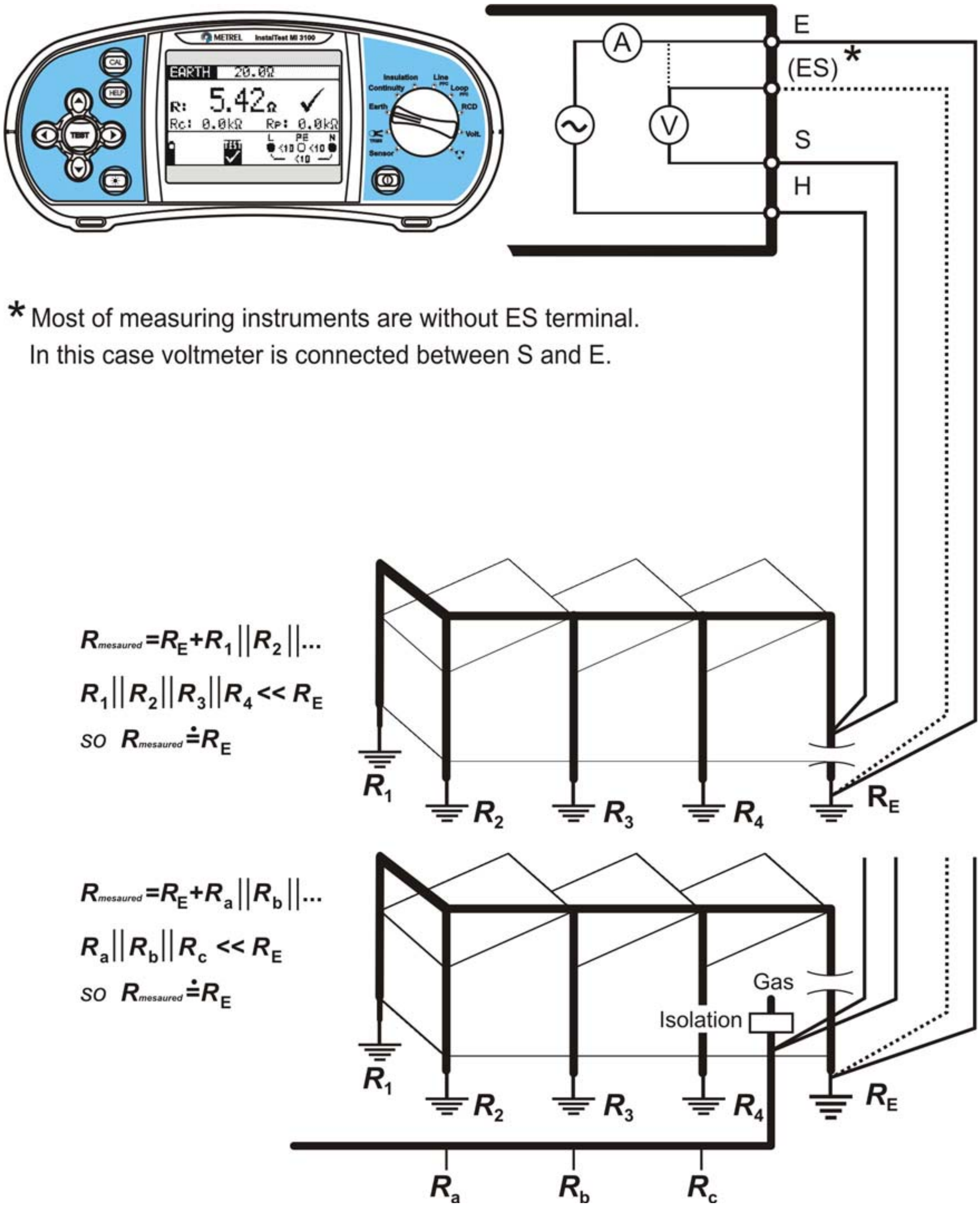
EXAMPLE 2

In this example parallel connection of resistances R1, R2, R3 and R4 is used as auxiliary test terminal.

As independent auxiliary test terminals the following systems can be used too:

- Gas installation system.
- Railway rail system.
- Water installation system (metal) etc.

It is assumed that the resistance of the auxiliary test terminal is small compared to the measured resistance.



Measuring procedure
- Set *EARTH* function.
- Set *EARTH 2,3,4W* subfunction (some models).
- Set test limit.
- Connect item under test.
- After pressing START key, test signal is applied between H and E terminals. Current starts to flow through the measured earthing resistance. The instrument measures test voltage between S (connected with E) and ES (connected with E) terminals and current. The earthing resistance result is calculated from both results. After that the instrument internally reconnects the AC generator, V and A-meter to measure the probe resistances. In the two-wire test probes are not used so the measured probe resistances must be ca. 0 Ω.

Notes
- If mains N conductor is used during the resistance test, eventual voltage noise can influence the results.
- To obtain correct results it must be assured that the resistance at the auxiliary terminal is small compared to the measured resistance.

Documentation
Global and local earthing resistances are one of the standard tests for verification of electrical installations.
For measurements at a certain test object, final test report is to be done, containing all parameters of the measurements like type of the measurement, type and serial number of the test instrument, test place, operator etc. Measurement results must be placed into appropriate columns of the final test report.

Regulations
Requirements for earth resistance measurements are defined in IEC/EN61557-5.
General requirements for equipment for testing safety of electrical installation are defined in IEC/EN 61557-1.

Exercise No. 3-1: Earth resistance measurement (two wire method) - Demoboard MI 2067

Simulation of faults with demoboard
Demonstration board enables measurements of earth resistance using two, three, four wire system as well as current clamp system.
The following earth resistances can be measured using the demonstration board:

- Resistance of Basic Grounding system BG.
- Resistance of Lightning earthing systems LR1 and LR2.

The following errors can be simulated:

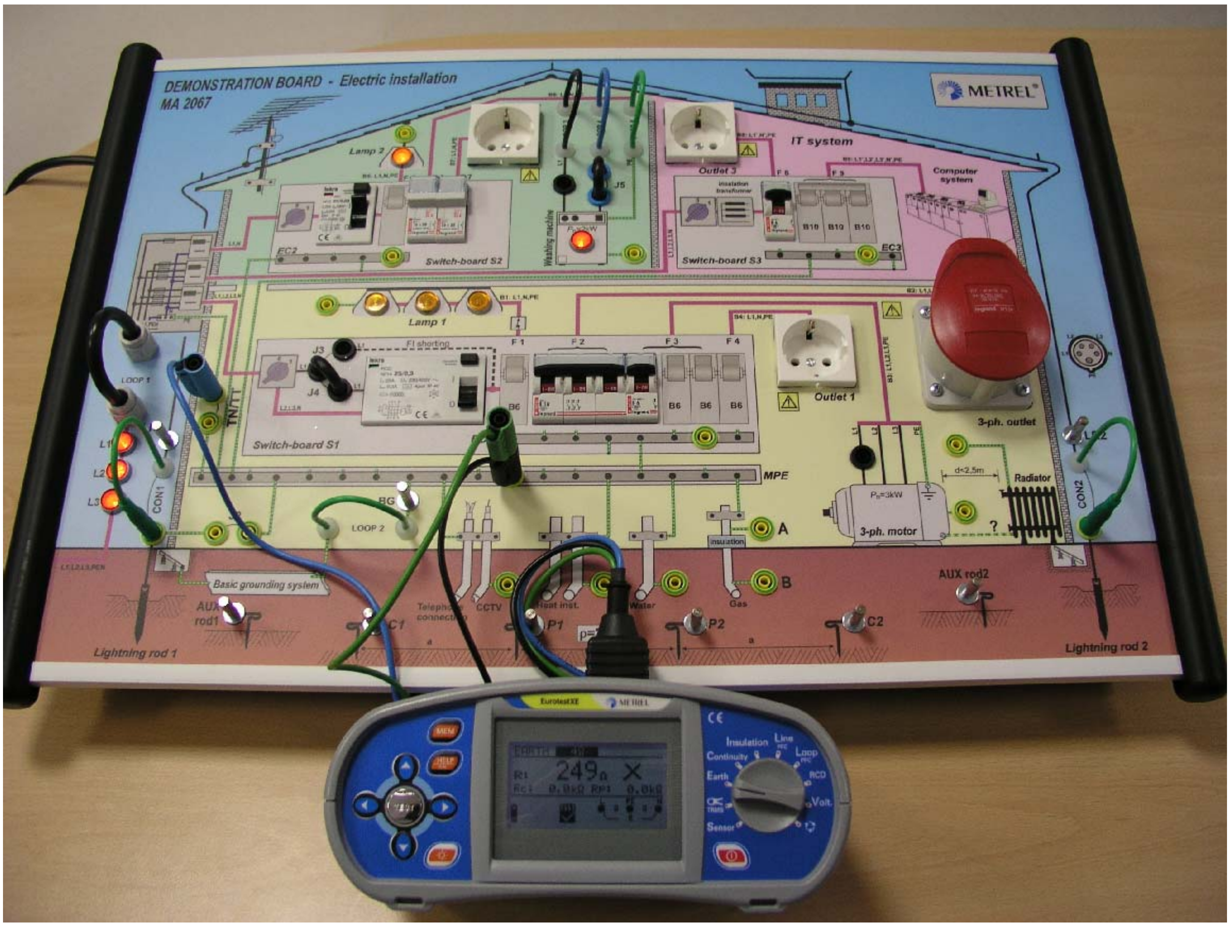
S12: Too high earth resistance of Basic Grounding system (approx. 250 Ω).
S13: Too high earth resistance of Lightning system 1 (additional resistance of approx. 100 Ω).

Example with demoboard

Example on figure below shows a two-wire measurement of global earthing resistance of the demoboard building. TT system is set. The test instrument is connected between N mains conductor (J1) and main potential equalizer MPE. N supply connection of demoboard is used as auxiliary terminal.

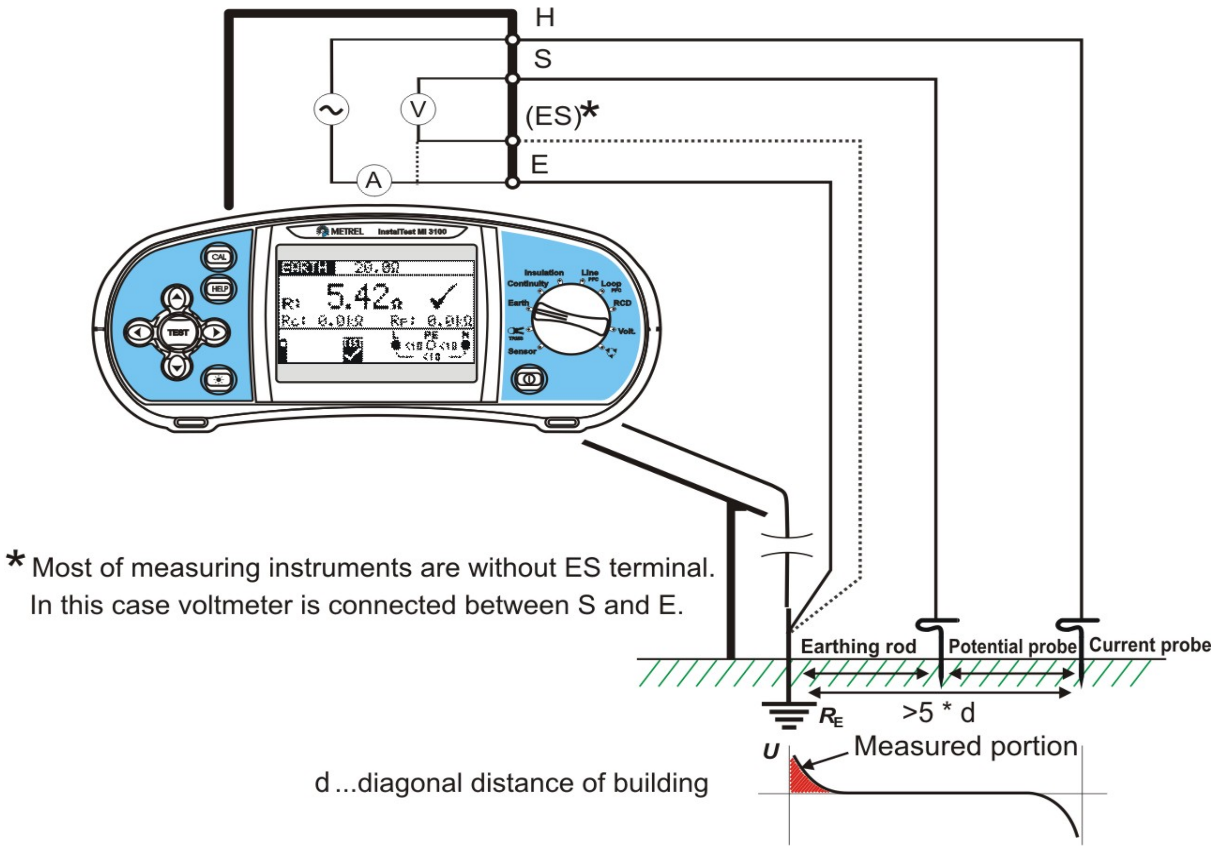
Demobard setup

Demoboard setup	*Condition*	*Notes*
S12 OFF	Resistance of basic grounding system ca.3 Ω	Normal condition
S12 ON	Resistance of basic grounding system ca.250 Ω	Fault in main earthing connection
M2 ON		To perform global earthing of building
J1 OFF		To set TT system
J2 OFF		To exclude lighting system from result



Exercise No.3-2: Earth Resistance Measurement (three wire method) - general

Measuring connection



Measuring procedure:

- Set EARTH function.
- Set EARTH 2,3,4 W subfunction (some models).
- Set test limit.
- Connect item under test.
- After pressing START key, test signal is applied between H and E terminals. Current starts to flow through the measured earthing resistance. The instrument measures test voltage between S and ES (E) terminals and current. The earthing resistance result is calculated from both results.
- After that the instrument internally reconnects the AC generator, V and A-meter to measure the probe resistances.

Note

- Resistance of current (H) and voltage (S) probes must be considered. If too high the results are impaired!
- Distances probe – probe and probe - object must be at least 5-times larger than the diagonal size of tested item.
- Noise signals that flow through the measured earth can disturb the results.

- METREL instruments automatically check the probes resistances during test.
- The three-wire test method can performed with three or four wires (terminals H, S, E or H, S, E, ES connected). If measuring with three wires the contact resistance of E probe is added to the result and must therefor be low.
- With the four-wire connection the contact resistance between E probe and tested metal surface is excluded from the result (with help of ES terminal).

Regulations
Specifications for earthing resistance measurements are covered in IEC/EN61557-5. General requirements for equipment for testing safety of electrical installation are defined in IEC/EN 61557-1.

Documentation
Global and local earthing resistances are one of the standard verification tests for electrical installations.
For measurements at a certain test object, final test report is to be done, containing all parameters of the measurements like type of the measurement, type and serial number of the test instrument, test place, operator etc. Measurement results must be placed into appropriate columns of the final test report.

Exercise No.3-2: Earth Resistance Measurement (three wire method) – Demoboard MI 2067

Simulation of faults with demoboard
Demonstration board enables measurements of earth resistance using two, three, four wire system as well as current clamp system. There are two auxiliary test terminals on front panel (AUXrod1, AUXrod2), which enable measurements using three and four wire test system.

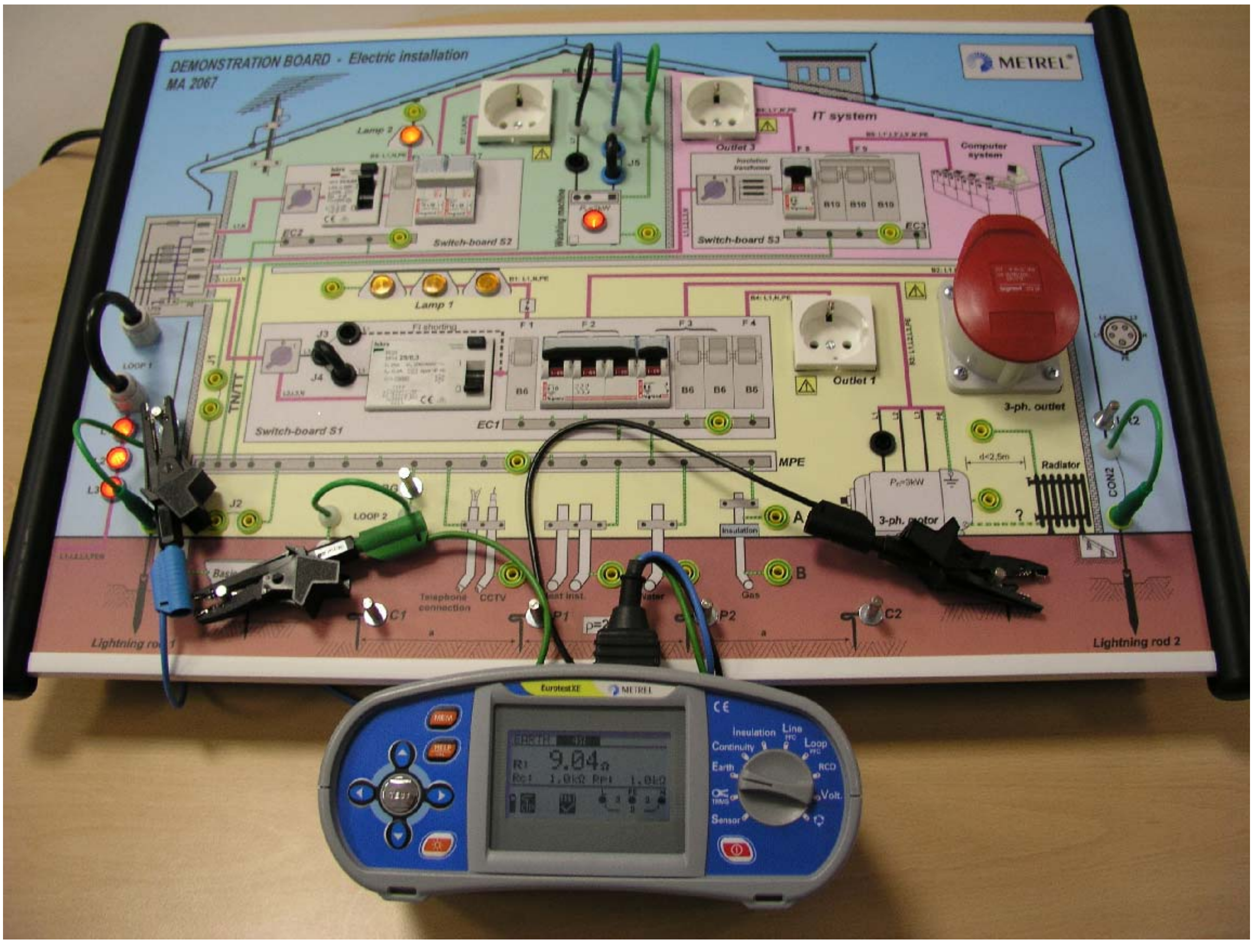
The following earth resistances can be measured using the demonstration board:
Resistance of Basic Grounding system BG.
Resistance of Lightning earthing system LR1 and LR2.

The following errors can be simulated:

S12: Too high earth resistance of Basic Grounding system (approx. 250 Ω).
S13: Too high earth resistance of Lightning system 1 (additional resistance of approx. 100 Ω).

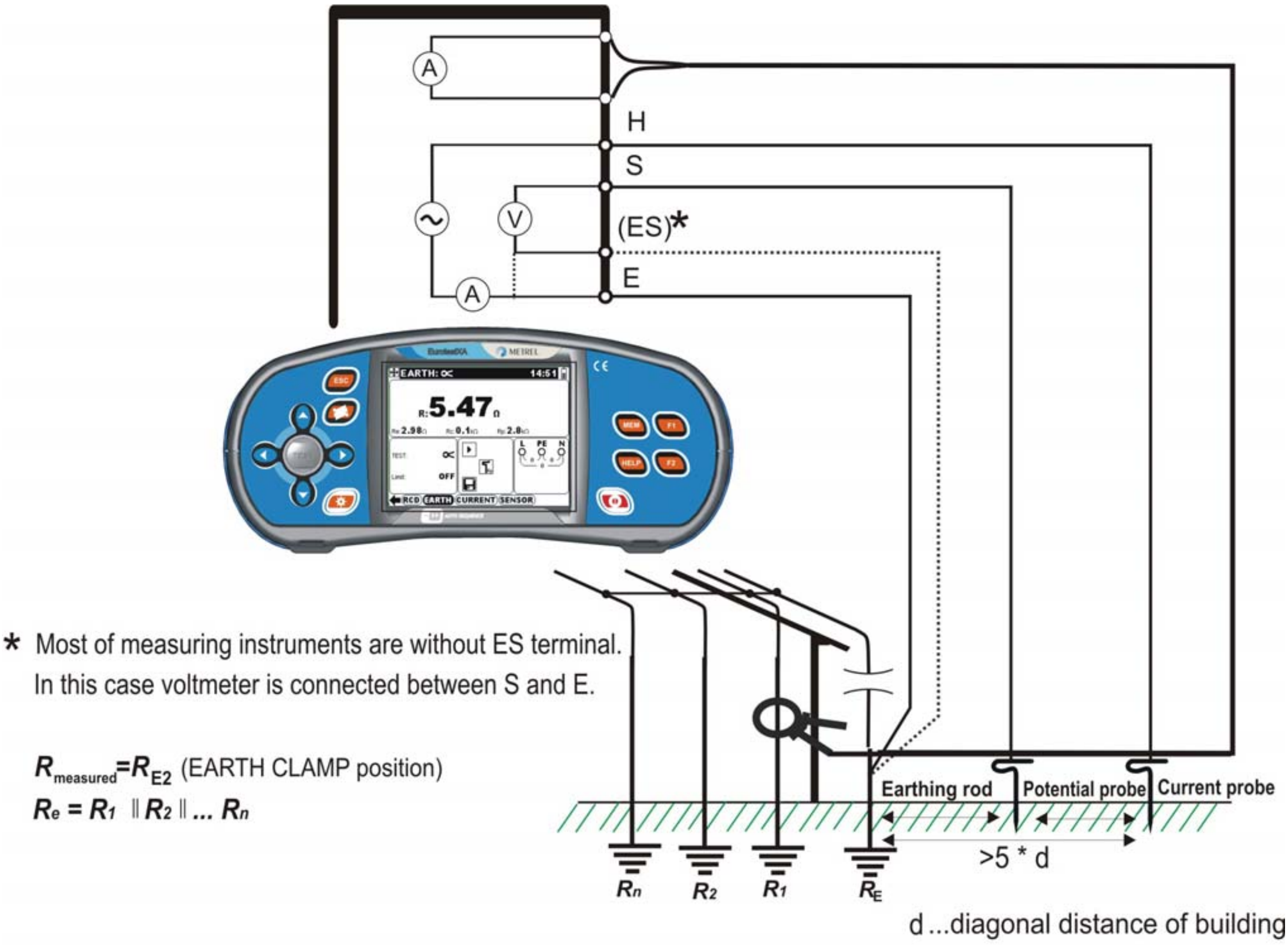
Example with demoboard
Example on figure below shows measurement of earthing resistance of the demoboard lighting system. The instrument is connected to simulated earthing probes AUXrod1(H), AUXrod2(S) and lighting rod 1.

Demoboard setup	*Condition*	*Notes*
S13 OFF	Resistance of lightning system ca.3 Ω	Normal condition
S13 ON	Resistance of lightning system ca.9 Ω	Fault in lighting system. Faulty rod can be found with one clamp method or with disconnection and measuring individual rods.
Conn1 ON Conn2 ON		To include complete lighting system
Jumper2 OFF		To exclude other earthing terminals



Exercise No. 3-3: Earth Resistance Measurement (current clamp method) - general

Measuring connection
In the example below the lighting system consists of more parallel connected earth bars. To measure earthing resistance of individual rods, instrument terminals must be connected to earthing system and to two auxiliary test rods according to the figure below. That way the instrument can calculate either total earthing resistance (EARTH function) or only the resistance of a certain earth bar using EARTH 1CLAMP function.



Measuring procedure
- Set EARTH function.
- Set EARTH 1CLAMP subfunction.
- Set test limit.
- Connect item under test.
- After pressing START key, test signal is applied between H and E terminals. Current starts to flow through the measured earthing resistance. The instrument measures test voltage between S and ES (E) terminals and current through the clamp. The selective earthing resistance is calculated from both results.

$$R_E = \frac{U_{\text{V-meter}}}{I_{\text{Clamp}}}$$

- After that the instrument internally reconnects the AC generator, V and A-meter to measure the probe resistances. The overall earthing resistance and probe resistances are available subresults.

Note

- Resistance of current (H) and voltage (S) probes must be considered. If too high the results are impaired!
- Distances probe- probe and probe-object must be at least 5-times larger than the diagonal size of tested item.
- Noise signals that are flowing through the measured earth can disturb the results.
- Noise currents that are flowing through the measured earthing rod can disturb the results.
- In large systems with many rods only a small portion of the measuring current is flowing through the clamp. If the clamp current is too small the results are impaired.
- METREL instruments check automatically the probe resistances and for eventual noise during test.

Regulations

Specifications for earth resistance measurements are defined in IEC/EN61557-5. General requirements for equipment for testing safety of electrical installation are defined in IEC/EN 61557-1.

Documentation

For measurements at a certain test object, final test report is to be done, containing all parameters of the measurements like type of the measurement, type and serial number of the test instrument, test place, operator etc. Measurement results must be placed into appropriate columns of the final test report.

Exercise No. 3-3: Earth Resistance Measurement (current clamp method) – Demoboard MI 2067

Simulation of faults with demoboard,

Demonstration board enables measurement of two separate earth resistances of Lightning system, as each of the two lightning earth bars is equipped with an appropriate clamp connection.

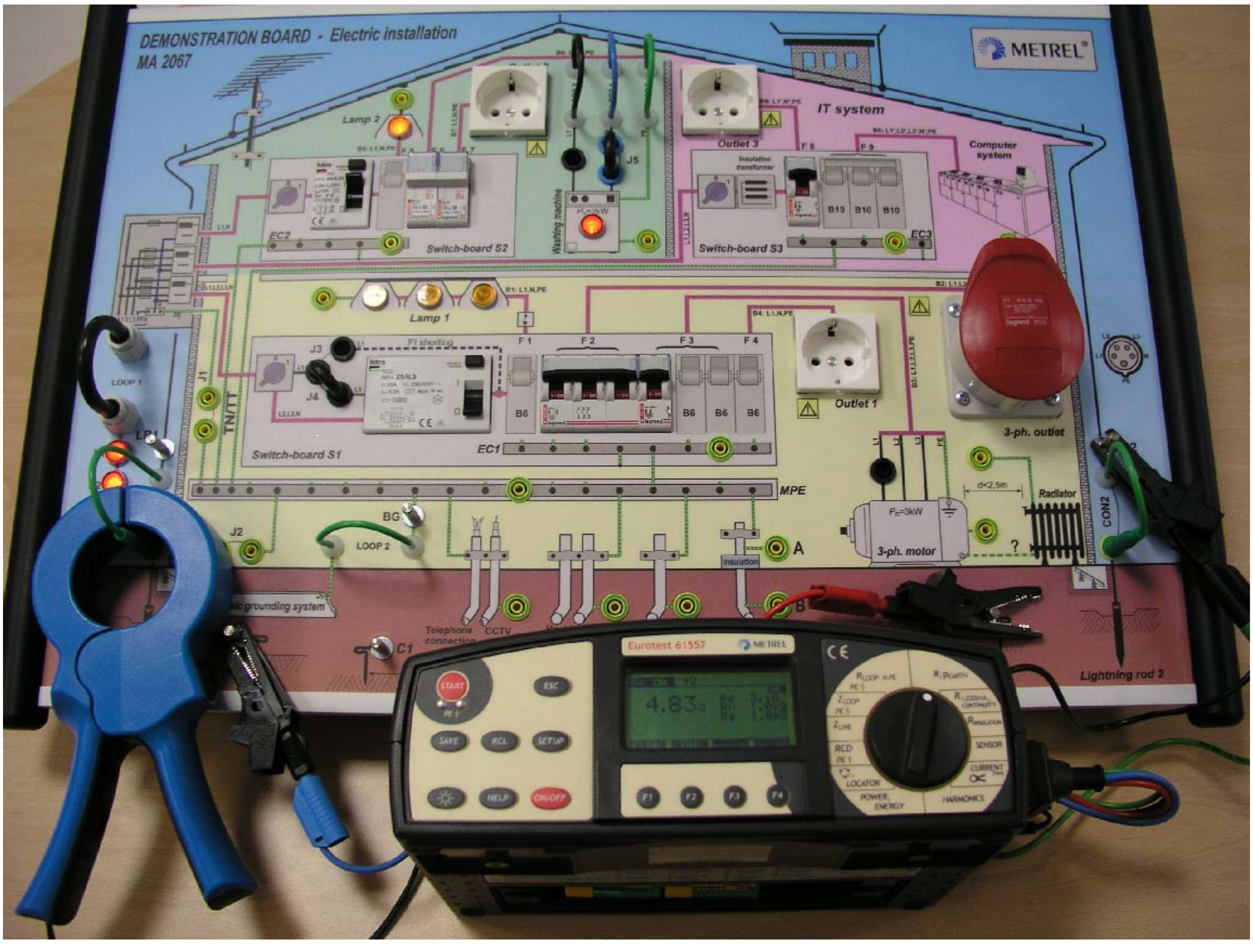
The following errors can be simulated:

S12: Too high earth resistance of Basic Grounding system (approx. 250 Ω).

S13: Too high earth resistance of Lightning system 1 (additional resistance of approx. 100 Ω).

Example with demoboard
Example on figure below shows measurement of earthing resistance of lighting rod 1. The lighting system consists of lighting rods 1 and 2. The instrument is connected to simulated earthing probes AUX rod1(H), AUX rod2(S) and lighting rod 2. Current clamp are connected to CONN1.

Demoboard setup	*Condition*	*Notes*
S13 OFF	Resistance of lightning rod ca. Ω	Normal condition
S13 ON	Resistance of lightning system ca.100 Ω	Fault on earhing rod
Conn2 ON Conn1 ON		To simulate earthing system with two rods.

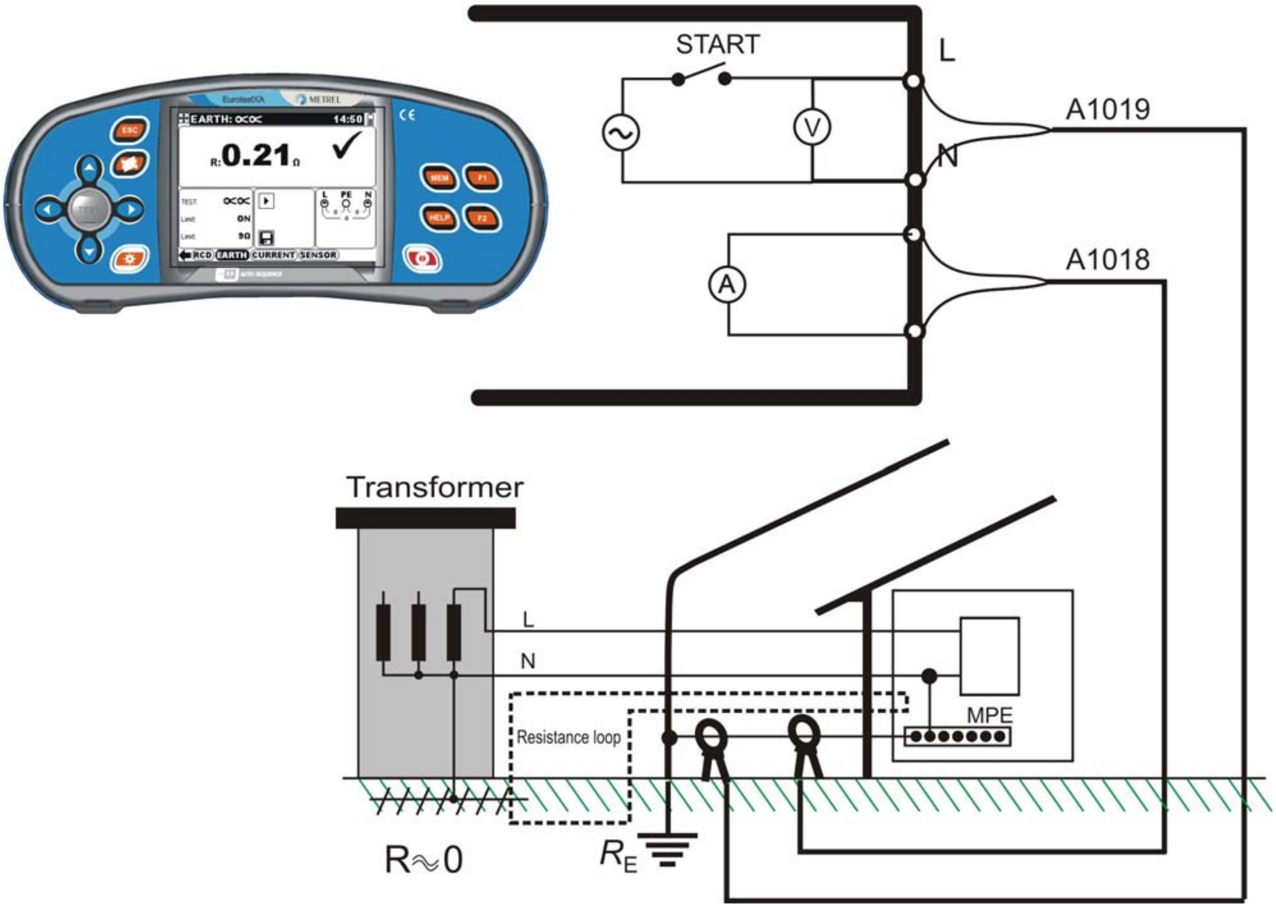


Exercise No.3-4: Earth Resistance Measurement (two current clamp method) - general

Measuring connection

EXAMPLE 1

In this example the measurement of system earthing in building performed with earthing probe in TN system is shown.
Measured loop consists of earthing of mains transformer, N conductor and system earthing of building. The earthing resistance of the transformer and resistance of N conductor must be small compared to the measured resistance.



Measuring procedure

- Set EARTH function.
- Set EARTH 2CLAMP subfunction.
- Set test limit.
- Connect both current clamps and item under test.
- After pressing START key, test signal is applied between H and E terminals. Test signal is driven through the measured loop with the generator clamp and measured with the leakage clamp

$$R_{\mathrm{E}} = \frac{U_{\mathrm{SOURCE}} \dfrac{1}{N_{GEN.CLAMP}}}{I_{\mathrm{LEAK.CLAMP}}}$$

U_{SOURCE} ....voltage of internal AC source
$N_{GEN.CLAMP}$ ......number of turns of generating current clamp
$I_{LEAK.CLAMP}$ ....current through the leakage clamp

Note
- Distance between clamps must be at least 30cm.
- Noise signals that are flowing through the measured earth can disturb the results.
- For a measuring loop resistance higher than 20Ω the leakage clamp current become too small to obtain accurate results.
- METREL instruments automatically detect too low clamp current and noise signals.

Regulations
There is no special regulation for two clamp measuring method but it will be recommended in new IEC 60364-6.

Documentation
For measurements at a certain test object, final test report is to be done, containing all parameters of the measurements like type of the measurement, type and serial number of the test instrument, test place etc. Measurement results must be placed into appropriate columns of the final test report.

Exercise No.3-4: Earth Resistance Measurement (two current clamp method) – Demoboard MI 2067

Simulation of faults with demoboard
Demonstration board enables measurements of earth resistance using two current clamp.

The following earth resistances can be measured using the demonstration board:

- Resistance of Basic Grounding system BG.
- Sum of resistances of Lightning earthing system LR1 and LR2.

The following errors can be simulated:

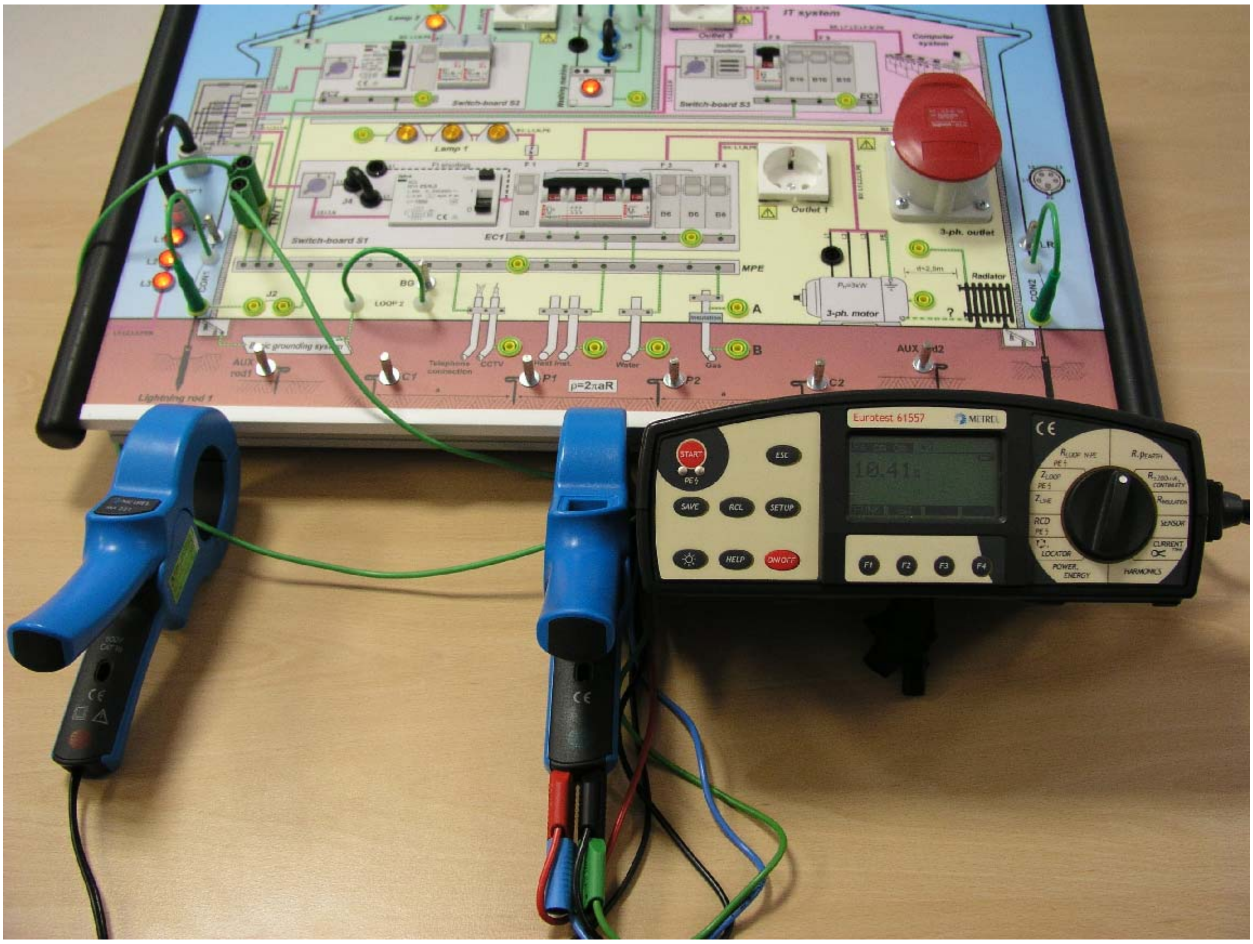
S12: Too high earth resistance of Basic Grounding system (approx. 250 Ω).
S13: Too high earth resistance of Lightning system 1 (additional resistance of approx. 100 Ω).

Example with demoboard

Example on figure below shows measurement of demoboard building basic grounding system. Measured loop consists of:

- Earthing of mains transformer, N conductor and PE conductor on which demoboard is connected.
- Earthing resistance of demoboard building's basic grounding system.

Demoboard setup	*Condition*	*Notes*
S12 OFF	Resistance of basic earthing system ca.10 Ω	normal condition
S12 ON (prolongation wire)	Resistance of basic earthing system ca.250 Ω	Fault on system earthing connection
JMP1 ON		to simulate TN system
JMP2 OFF		To exclude lighting system



4. Earth resistivity measurement

Background of measurement
Earth resistivity measurement is usually carried out when testing structure of soil in order to use this information for further designing of earthing system (length and deepness of earth rods). Usually Wenner's method is used for the measurement. Earth resistivity is calculated as follows:

$\rho = 2 \cdot \pi \cdot a \cdot R$

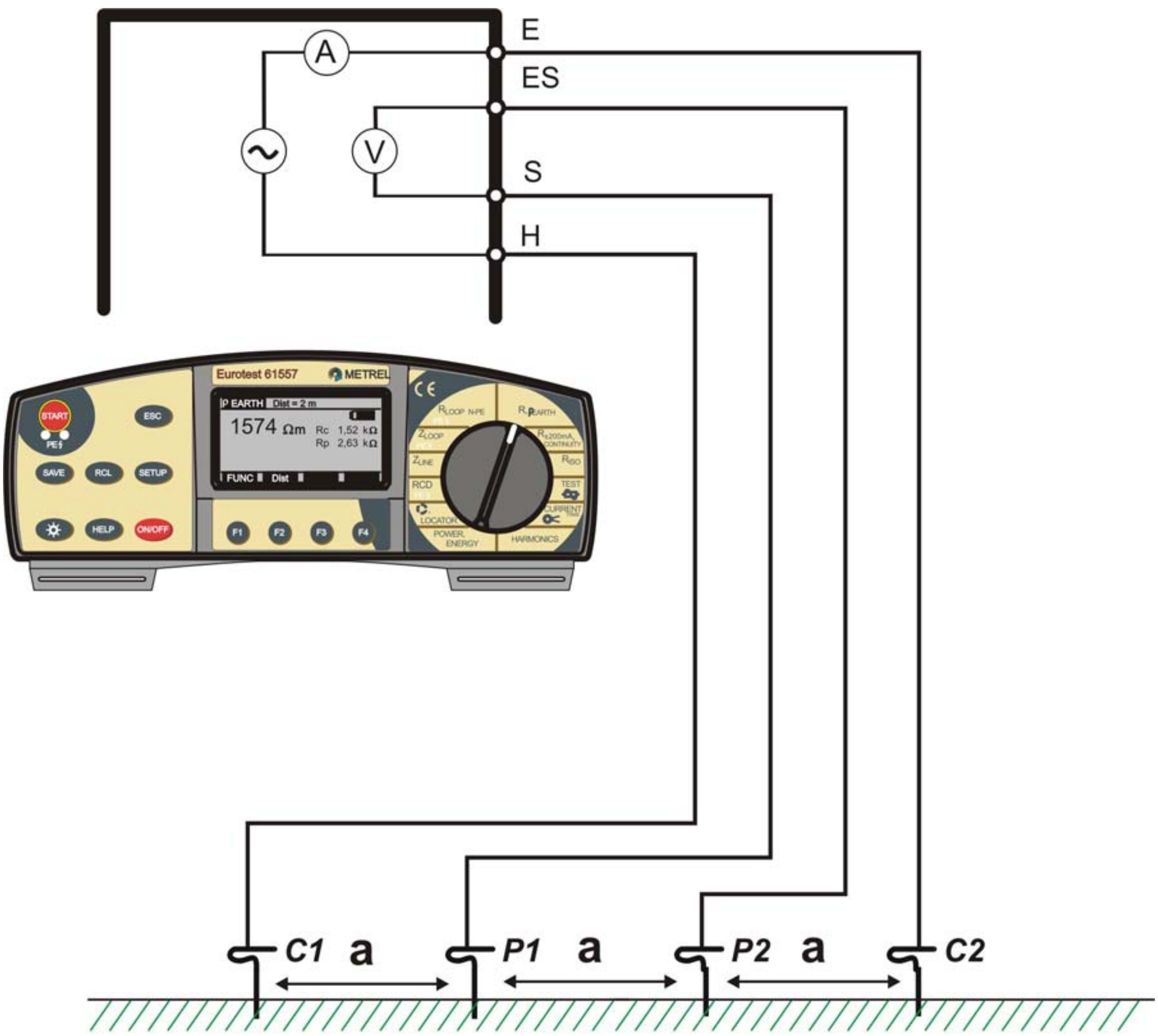
where:
ρ .... earth resistivity (in Ωm),
a .... distance between two test rods (in m),
R........... measured value of resistance between P1 and P2 auxiliary test rods (in Ω).

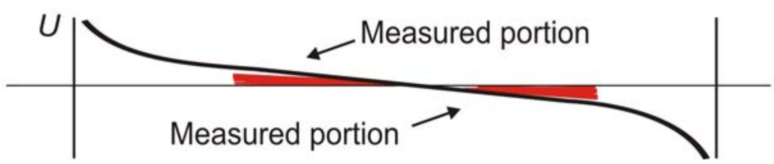
The soil included in the measurements depends on the distance between the measuring probes. Homogenity of soil eg. evaluation of soil structure in different depths can be evaluating by changing the distance a. Relation between distance and measured depth can be found in appropriate METREL documents.

Only instruments equipped with four test terminals and internal generator can perform this measurement.

Exercise No.4-1: Earth resistivity measurement - general

Measuring connection





Measuring procedure

- Set EARTH function.
- Set EARTH ρ subfunction.
- Set test parameters (distance between rods).
- Set test limit.
- Place the probes and connect them to the instrument.
- After pressing START key, test signal is applied between H and E terminals. Current starts to flow through the measured earthing resistance. The instrument measures test voltage between S and ES (E) terminals. After that the instrument internally reconnects the AC generator, V and A-meter to measure the probe resistances.

Note

- Resistance of current (H, E) and voltage (S, ES) probes must be considered. If too high the results are impaired!
- Relation between distance between and depth of measured soil layer must be known.
- METREL instruments check the probe resistances and for eventual noise during each instrument.
- A series of measurements must be performed to get proper data about soil structure and homogenity.

Regulations

Specifications for earthing resistance measurements are covered in IEC/EN61557-5. General requirements for equipment for testing safety of electrical installation are defined in IEC/EN 61557-1.

Documentation

For measurements at a certain test object, final test report is to be done, containing all parameters of the measurements like type of the measurement, type and serial number of the test instrument, test place, operator etc. Measurement results must be placed into appropriate columns of the final test report.

Exercise No.4-1: Earth resistivity measurement – Demoboard MI 2067

Simulation of fault with demoboard

Demonstration board enables to set four different distances between auxiliary rods, so four different resistances between test terminals P1 and P2 can be measured. It is important to know that earth resistivity will always be the same in all four cases as the measurements are meant to be done at the same, homogenous soil.

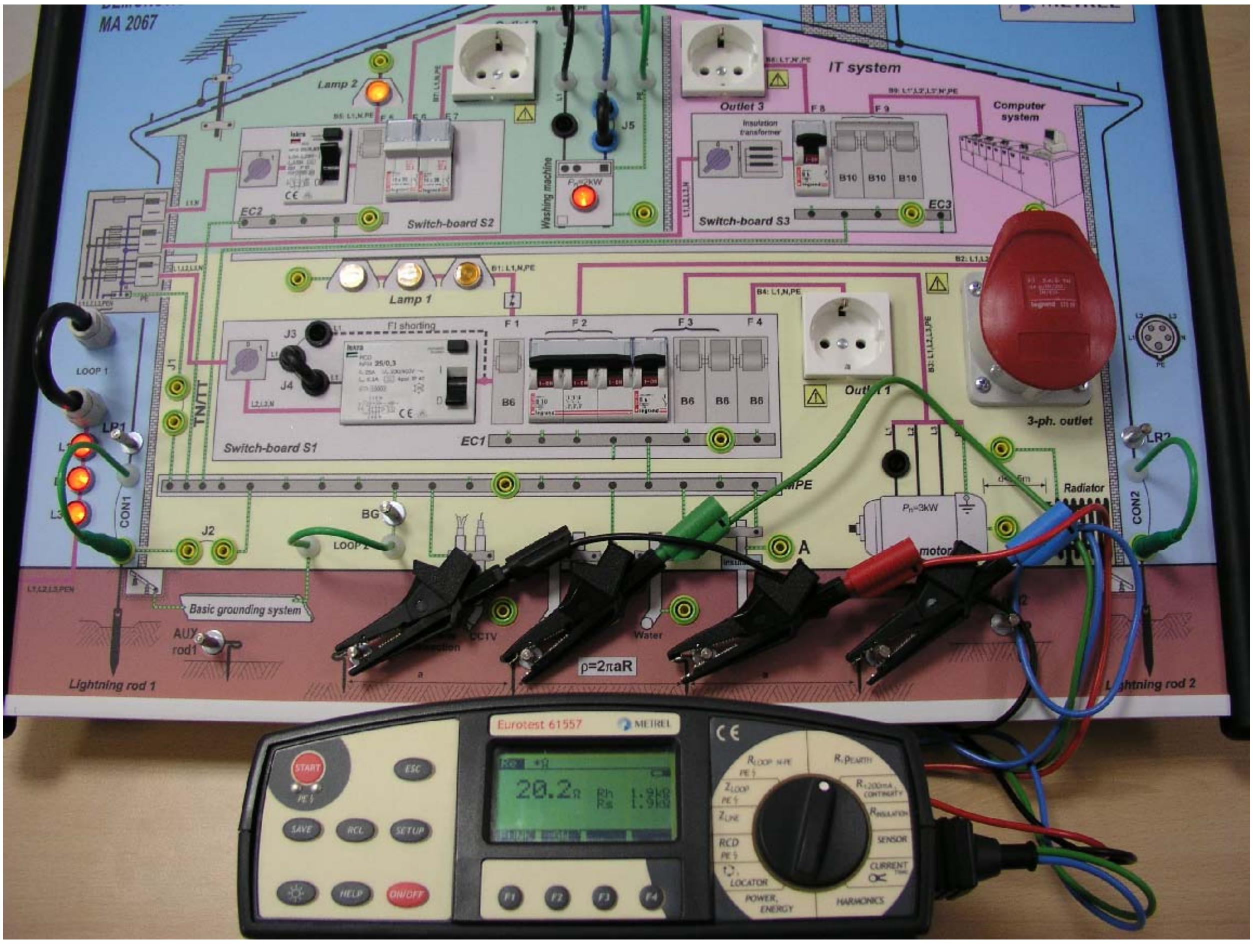
The following values of resistance R and distances a can be selected using switches S14 and S15:

S14	off,	S15	off:	a = 1m,	R = 20 Ω,
S14	on,	S15	off:	a = 3m,	R = 6,7 Ω,
S14	off,	S15	on:	a = 10m,	R = 2 Ω,
S14	on,	S15	on:	a = 12m,	R = 1,67 Ω.

Example with demoboard

Example on figure below shows typical soil resistivity measurement. The instrument terminals are connected to simulated earthing probes C1(H), P1(S),P2(ES) and C2(E).

Demoboard setup	*Condition*	*Notes*
S14 ON/OFF S15 ON/OFF	1,67 Ω to 20 Ω (as in table above)	To simulate behavior of results in homogenous soil.



5. Fault loop impedance measurement

Background of measurement
In TN system all accessible metal parts are connected to neutral conductor N via protection earth conductors PE and thus to ground by means of earthing system of power transformer.
Safety conditions are checked by measuring loop impedance (Z_{LOOP} or R_{LOOP}) and calculating prospective fault current I_{PFC}.

The fault loop impedance
$Z_{LOOP} = Z_L + Z_{PE} + Z_{NPE} + Z_T$
consists of:

- Z_L............. phase conductor
- Z_{PE}........... protection earth conductor (in building)
- Z_{NPE}.......... common neutral / protection earth conductor from mains transformer to building
- Z_T .... transformer

The prospective fault current is calculated from

$I_{PFC} = U_{LPE} / Z_{LOOP}$
with
- U_{LPE}.......... rated fault loop voltage.

Overcurrent disconnection device must be designed to trip out in case of an earth fault, i.e. short circuit of line to earth (PE). Limit currents and impedance depend on selected fuse type, size and required trip out time.
Where TN installation is protected with a RCD, special measuring techniques are used to avoid tripping out the RCD during the test. Allowed values of fault loop impedance / resistance depend on required trip out time, which can be found in appropriate literature.

In TT system, all accessible metal parts are connected to basic grounding system of the building via protection earth conductor PE. Safety conditions are checked by measuring earth resistance RE.

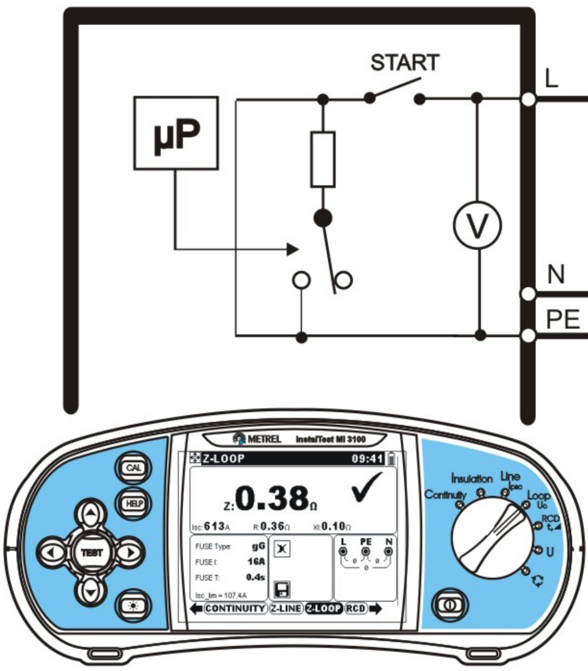
The fault loop impedance
$Z_{LOOP} = Z_L + Z_E + Z_T + Z_{ET}$
consists of:

- Z_L............. phase conductor
- Z_E .... global earthing of building + PE conductor in building
- Z_{ET}........... earthing of supply system
- Z_T .... transformer

RCD devices are usually used as protection elements in TT system. In case of short circuit or a high leakage current between phase and PE conductor contact voltage occures on accessible metal parts. The voltage must stay below 50 V (25 V for aggravating conditions) otherwise the RCD must trip out:

Exercise No.5-1: Fault loop impedance and prospective fault current measurement in TN system - general

Measuring connection



Measurement procedure

- Set LOOP function.
- Select LOOP test method (some instruments, standard or trip lock)
- Set test parameters if applied (fuse type, size, trip out time)
- If test parameters are applied test limit (impedance or prospective fault current) is set automatically.
- Connect item under test.
- After pressing START key test instrument loads the installation between L and PE terminals and measures loaded and unloaded voltages. The result is obtained by following formula (simplified form).

$$R_{LOOP} = \frac{U_{UNLOADED} - U_{LOADED}}{(U_{LOADED} / R_{LOAD})}$$

If phase delays are measured loop impedance Z_{LOOP} can be calculated.

$Z_{LOOP} = R_{LOOP} + j\omega L_{LOOP}$.

Notes

- Specified accuracy of loop impedance measurement is valid only if mains voltage is stable during the measurement!
- If RCD is installed it is likely that it will trip during the standard test. In modern loop testers alternative measuring functions can be selected that will not trip the RCD (“trip lock” etc). In general this measurements are more influenced by unstable mains voltage than the standard one. There are huge differencies in the accuracy and noise immunity of trip lock methods between different producers!

Regulations

Specifications for loop impedance measurements are covered in IEC/EN 61557-3. General requirements for equipment for testing safety of electrical installation are defined in IEC/EN 61557-1.

Documentation

Loop impedance is one of the standard verification tests for electrical installations. For measurements at a certain test object, final test report is to be done, containing all parameters of the measurements like type of the measurement, type and serial number of the test instrument, test place etc. Measurement results must be placed into appropriate columns of the final test report.

Exercise No.5-1: Fault loop impedance and prospective fault current measurement in TN system – Demoboard MI 2067

Simulation of fault with demoboard

Demonstration board enables measurements of fault impedance at the following loops:

Lamp 1, Lamp 2, 3-phase motor, 3-phase outlet, computer system, protection earth collector 2, gas installation and hot water installation.
In above listed loops unacceptably high resistance can be simulated setting switches S4 to S11 to “fault” position. The following values of fault loop impedance can be set:

S4: current loop L1 - PE of computer system: >20 Ω
S5: current loop L1 - PE of lamp 2: approx. 2,7 Ω
S6: current loop L1 - PE of 3 - phase motor: approx. 3,3 Ω
S7: current loop L1 - PE of lamp 1: >20 Ω
S8: current loop L1 - PE of 3 - phase outlet: >3,4 Ω
S9: current loop L1 - Protection earth collector 2: approx. 2,2 Ω
S10: current loop L1 - Gas installation: approx. 3,3 Ω
S11: current loop L1 - Hot water installation: approx. 3,3 Ω

Example with demoboard

Demoboard setup	*Condition*	*Notes*
Sxy OFF	Resistance of basic earthing system ca. Ω	Normal condition
Sxy ON	Resistance of basic earthing system ca. Ω	Fault
JMP1 ON		To simulate TN system
Switch board xy: RCD, fuses ON Jumper M4 ON		Mains voltage on, trip lock test method recommended
Switch board xy: RCD OFF, fuses ON, Jumper M3 ON		Mains voltage on, standard test method recommended

6. Line impedance measurement

Background of measurement
Line impedance is important for supplying electrical equipment. The line impedance:

$Z_{LINE} = Z_L + Z_N + Z_T$

consists of:
- Z_L.............line conductor,
- Z_N ....neutral conductor,
- Z_T ....transformer.

The measurement of line impedance is important for:

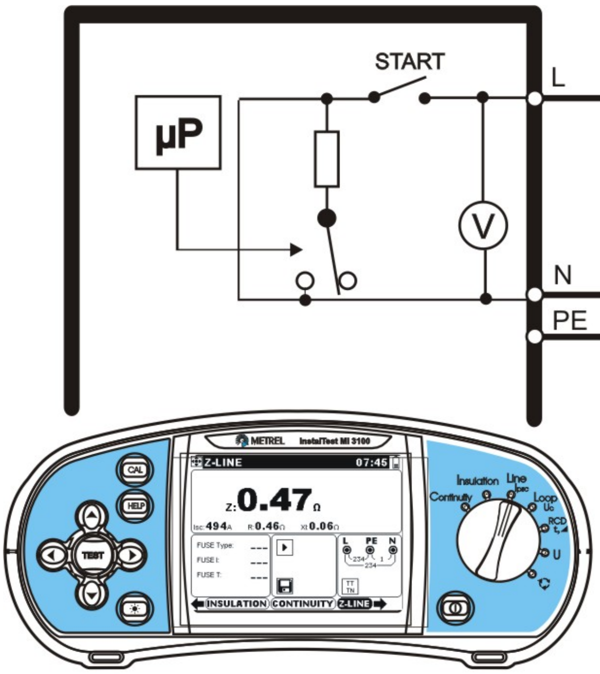
- Checking the effectiveness of installed overcurrent disconnection devices.
- Locating of too high (excessive) line impedance that causes too high voltage drop between power transformer and a load.

Similar to Z_{LINE} is $Z_{LINE-LINE}$. In this case Z_L of second line replaces Z_N.

Faults (bad contacts, corrosion) or improper installation design are the most often reason for too high line impedances and wrong installed fuses.
Safety conditions are checked by measuring line impedance (Z_{LINE} or R_{LINE}) e.g. prospective short circuit current I_{PFC}. Limit currents and impedance usually depend on fuse type, size and required trip out time.
Line resistance or line impedance can be measured. The resistance measurement returns only the resistive part of the loop. The impedance measurement considers the inductive part too. In general impedance measurement is preferred if the measurement is performed close to the transformer or on the installation with high rated currents. In this case the contribution of the inductive part is relatively high.

Exercise No.6-1: Line impedance and prospective short circuit current measurement - general

Measuring connection



Measurement procedure

- Set LINE function.
- Set test parameters if applied (fuse type, size, trip out time)
- If test parameters are applied test limit is set automatically.
- Connect item under test.
- After pressing START key test instrument loads the voltage between L and N terminals and measures loaded and unloaded voltages. The result is obtained by following formula (simplified form).

$$R_{LINE} = \frac{U_{UNLOADED} - U_{LOADED}}{(U_{LOADED} / R_{LOAD})}$$

If phase delay is measured loop impedance Z_{LINE} can be calculated.

$Z_{LINE} = R_{LINE} + j\omega L_{LINE}$.

Notes

- Specified accuracy of line measurement is valid only if the mains voltage is stable during the measurement! In general this is not a big problem since the test current is high.
- $Z_{LINE-LINE}$ can be measured on 3-phase outlet only in the case of 3-phase connection of the demoboard.

Regulations
Specifications for earthing resistance measurements are covered in IEC/EN 61557-3. General requirements for equipment for testing safety of electrical installation are defined in IEC/EN 61557-1.

Documentation
Line impedance is one of the standard verification tests for electrical installations. For measurements at a certain test object, final test report is to be done, containing all parameters of the measurements like type of the measurement, type and serial number of the test instrument, test place, operator etc.. Measurement results must be placed into appropriate columns of the final test report.

Exercise No.6-1: Line impedance and prospective short circuit current measurement – Demoboard MI 2067

Simulation of fault with demoboard
Demonstration board enables measurements of line impedance at the following current loops:

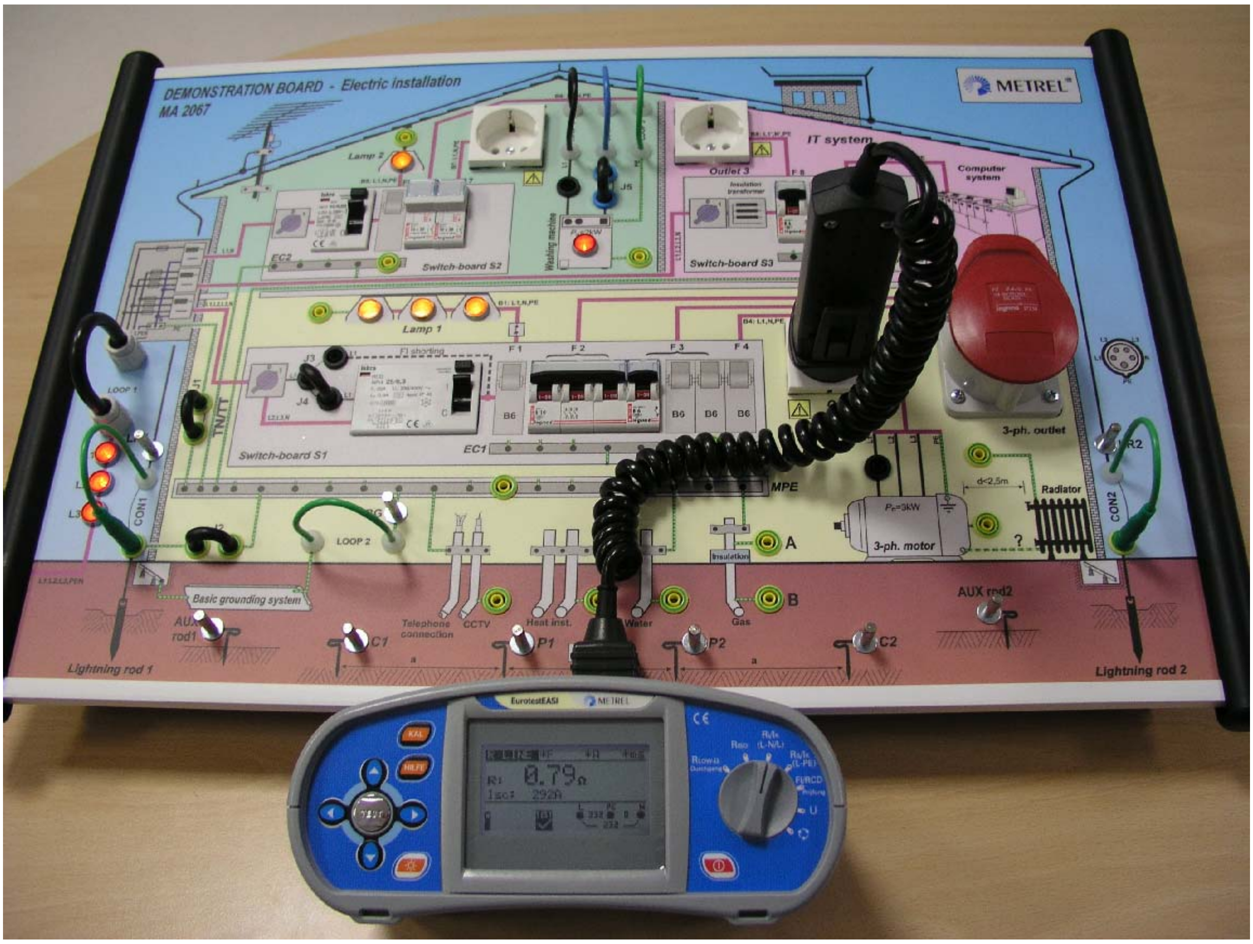
switch board S1: Outlet 1 and 3-phase outlet
switch board S2: Outlet 2
switch board S3: Outlet 3

In above listed current loops unacceptably high resistance can be simulated setting switches S1 to S3 to “fault” position. The following values of line impedance can be set:

S1: current loop L3 - N at 3- phase outlet: >10 Ω
S2: current loop L1 - N at outlet 2: >10 Ω
S3: current loop L1 - N at outlet 1: >10 Ω
current loop L1’ - N’ at outlet 3: 100 Ω (continuously present regardless of switches)

Example with demoboard

Demoboard setup	*Condition*	*Notes*
Sxy OFF	Line impedance ca Ω	normal condition
Sxy ON	Line impedance ca.Ω	fault
Switch board xy: RCD, fuses ON Jumper M4 ON		mains voltage on


DEMONSTRATION BOARD - Electric installation
MA 2067
METREL
IT system
Lamp 2
Lamp 1
Washing machine
Outlet 3
Computer system
Switch-board S2
Switch-board S3
Switch-board S1
TN/TT
EC2
EC1
F1
F2
F3
F4
B6
3-ph. outlet
LOOP 1
LOOP 2
CON1
CON2
MPE
A
B
3-ph. motor
Radiator
Basic grounding system
Telephone connection
CCTV
Heat inst.
Water
Gas
AUX rod2
C1
P1
P2
C2
Lightning rod 1
Lightning rod 2
EurotestEASI
0.79

7. Measurement of RCD paramaters

Background of measurement
RCD protection switches are used to protect users of electric appliances against electric shock caused by fault and leakage currents in the installation. Even relatively small currents are dangerous if resistance to earth and equipotential bonding are relatively high. Typical fault reasons are deteriorated insulation, dirt, moisture, filter capacitors etc.

Function of RCD
In TN system, fault and leakage currents flow from live conductors to protection earth conductor and then through PEN conductor to neutral terminal of power transformer. The RCD must trip out if the leakage (fault) current exeeds its nominal current:

$I_{FAULT,\ LEAKAGE} \leq I_{\Delta N}$

It must be assured that the fault and leakage currents do not cause touch voltages higher than conventional safety limit of 50(25)V.

$Z_{LOOP} \cdot I_{\Delta N} \leq U_C$

Impedances in TN systems are usually much lower than allowed (for example: impedance of fault loop protected by RCD protection device with rated differential current of 30 mA could be as high as 1666 Ω, while actual values are lower than 2 Ω).

In TT system, fault currents supplied by line voltage flow through the fault to protection earth conductor (PE) and then to ground via system earthing resistance. The current is droved to grounding system of power transformer and thus to neutral terminal of the transformer. Total impedance of the fault loop consists of more serial impedances, where the major part presents global resistance of earthing system; other impedances are negligible in comparison with this resistance. Following condition must be fulfilled:

$R_E \, . \, I_{\Delta N} \leq U_C$
where:

R_E............ global earthing resistance in Ω,
$I_{\Delta N}$............ nominal differential current of RCD,
U_C............ limit contact voltage (50V or 25 V).

RCD parameters
RCD test parameters (test current shape, size) must be set correctly before the test. Disconnection time $t_{\Delta N}$ and actual disconnection currents I_{Δ} are measured. A complete analysis of the proper operation of installed RCD includes:

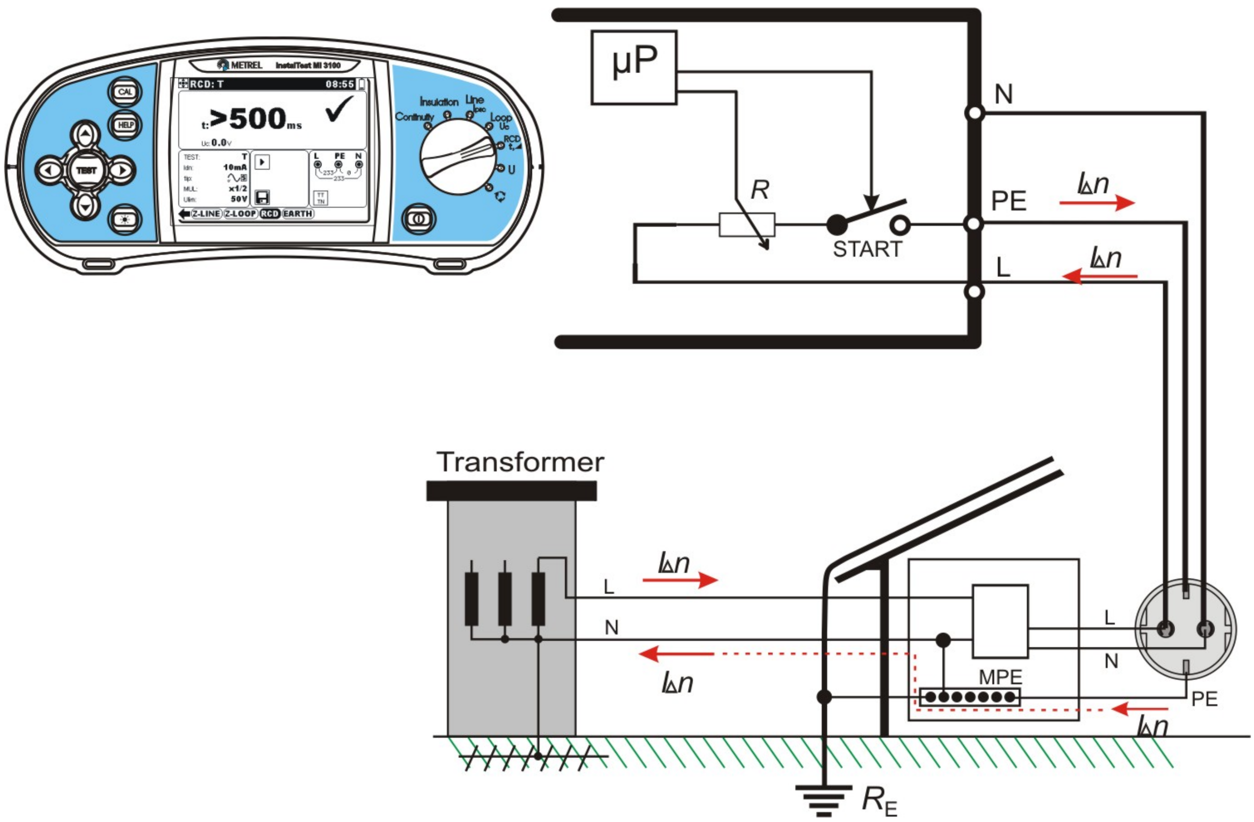
- disconnection times $t_{\Delta N}$ at ½, 1 and 5 $I_{\Delta N}$
- contact voltage test.

Limit values are defined in appropriate standards and are usually inbuilt in measuring equipment.

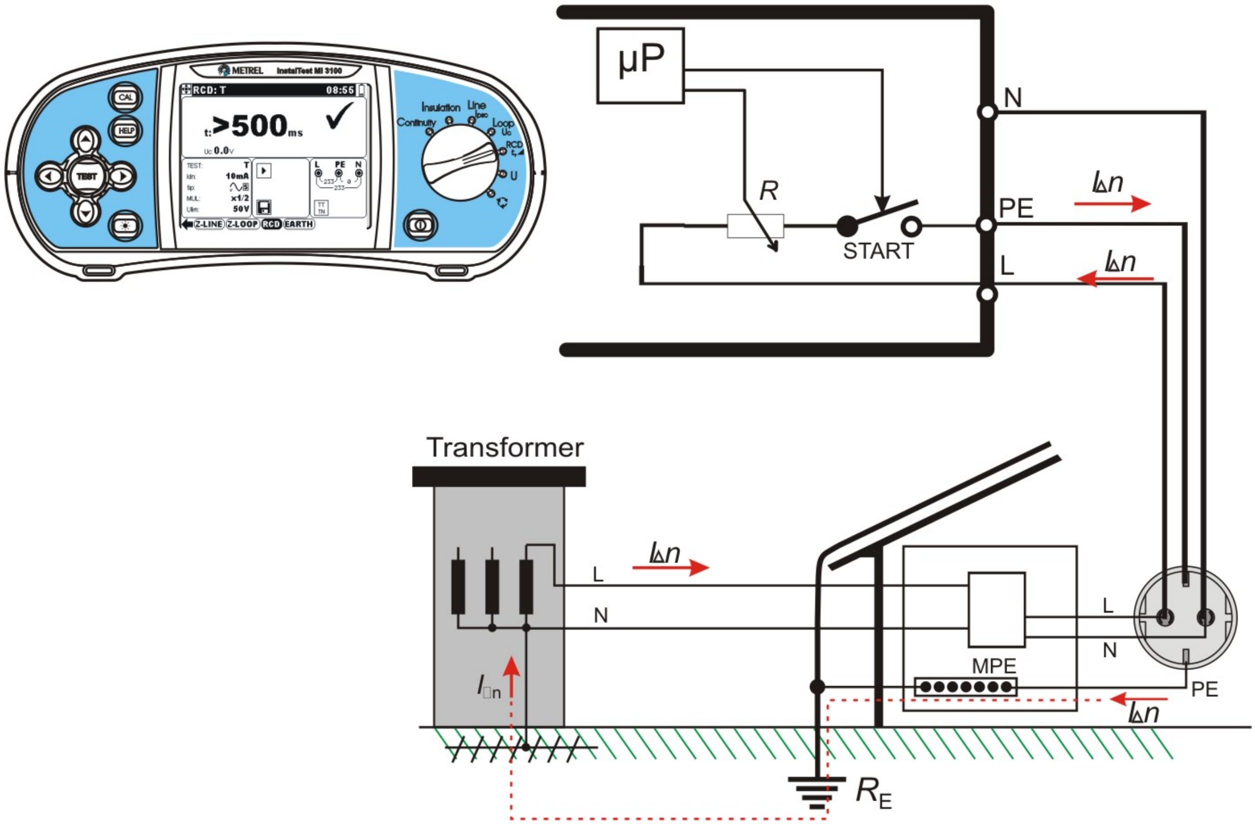
Exercise No.7-1: Testing of installed RCDs - general

Measuring connection

EXAMPLE 1
In that example RCD test in a TN system is shown.



EXAMPLE 2
In that example RCD test in a TT system is shown.



Measurement procedure

- Set RCD function.
- Set RCD subfunction (tΔN, IΔ, AUTO,Uc (RS))
- Set test parameters (IΔN, multiplikator, RCD type, test current starting polarity). Test limit is set automatically.
- Connect item under test. After pressing START key test the instrument drives test fault current from phase terminal to PE terminal.The instrument can measure actual trip out current, trip out time at nominal tripout current, contact voltage.

Notes

- The measurement of contact voltage and ½ IΔN usually does not trip an RCD. However, the trip limit may be exceeded because of leakage current flowing to the PE protective conductor or capacitive connections between L and PE conductors. This must be considered as a leakage problem and not as a problem of the RCD itself.

Regulations

Specifications for RCD testing requirements in TN / TT systems are defined in IEC/EN 61557-6.
General requirements for equipment for testing safety of electrical installation are defined in IEC/EN 61557-1.
Maximum allowed disconnection times for RCDs are defined in IEC/EN 60755, IEC/EN 61008 and IEC/EN 61009.

Documentation
RCD operation and contact voltage test are one of the standard verification tests for electrical installations.
For measurements at a certain test object, final test report is to be done, containing all parameters of the measurements like type of the measurement, type and serial number of the test instrument, test place etc. Measurement results must be placed into appropriate columns of the final test report.

Exercise No.7-1: Testing of installed RCDs – Demoboard MI 2067

Simulation of faults with demoboard
Two switchboards on demonstration board are RCD protected. The RCD operation can be checked on Outlets 1, 2, and 3-phase outlet.
If TT system is selected different values of resistances to earth can be set to check the effectiveness of the installed RCD:

- Resistance of Basic Grounding system BG.
- Resistance of Lightning systems LR1 and LR2.

The following errors can be simulated:

S12: Too high earth resistance of Basic Grounding system (approx. 250 Ω).
S13: Too high earth resistance of Lightning system 1 (additional resistance of approx. 100 Ω).

The 250 Ω value is too high for the RCD ($I_{\Delta N}$ = 0,3 A) in switchboard 1. If both lightning rods are connected parallel to the Basic Grounding, total resistance will meet safety requirement for the RCD regardless of switch S13.

Example with demoboard
In this example RCD operation test in switchboard S1 is shown.

Demoboard setup	*Condition*	*Notes*
S12 OFF	Earthing resistance ca xy Ω	Normal condition
S12 ON	Earthing resistance ca. 250 Ω	Too high contact voltage
Switch board 1: RCD, fuses ON Jumper M4 ON Jumper 1 OFF Jumper 2 OFF		Mains voltage on, RCD protected installation TT system
Conn 1 OFF Conn 2 OFF		To exclude (separate) lighting system from the earthing system


DEMONSTRATION BOARD - Electric installation
MA 2067
METREL
Lamp 2
IT system
Outlet 3
Computer system
Switch-board S2
Switch-board S3
Washing machine
Lamp 1
Switch-board S1
EC1
EC2
TN/TT
LOOP 1
LOOP 2
CON1
CON2
MPE
3-ph. outlet
3-ph. motor
Radiator
Basic grounding system
Telephone connection
CCTV
Heat inst.
Water
Gas
A
B
C1
P1
P2
C2
Lightning rod 1
Lightning rod 2
18ms

8. Leakage current measurement

Background of measurement

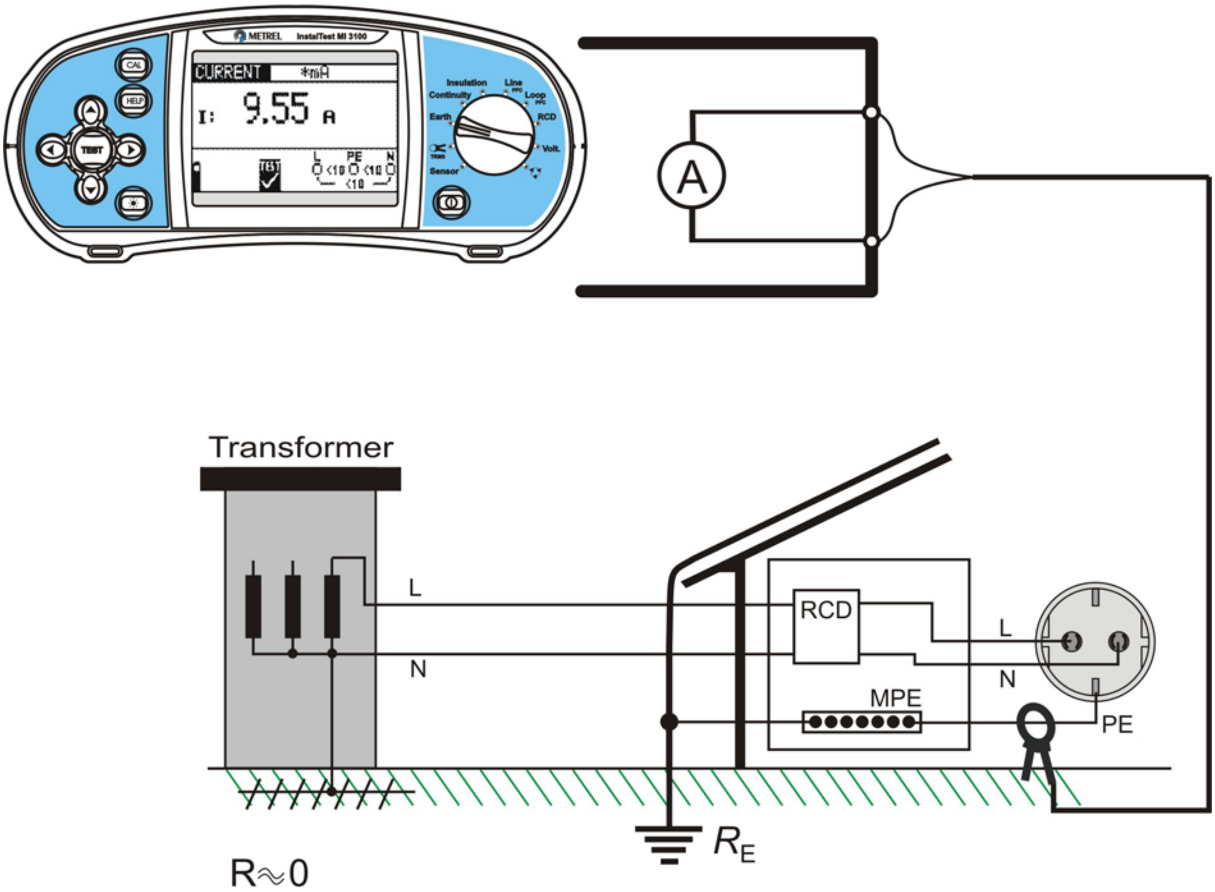
Leakage and fault currents are caused by appliance EMC filters and because of non-ideal insulation resistances in appliances and installation. Leakage currents increase with the size of installation and number of devices connected to it. If the sum of these currents exceeds the expected level they can cause different troubles like tripping of RCDs.

If the installation protective measures are improper, excessive leakage and fault currents can result in dangerous contact voltages in the system.

Leakage currents can be easily measured with high quality current clamps.

Exercise No. 8-1: Leakage current measurement with current clamp - general

Measuring connection



Measuring procedure

- Set CURRENT function.
- Set TRMS CURRENT subfunction (some models)
- Set limit value.
- Connect current clamp.
- After pressing START key test the instrument measures the TRMS value of current flowing through the clamp.

Notes

- The clamp current measurement could be influenced by near EM fields (caused by high load currents in line conductors, large metal surfaces on high voltage in fuse cabinets, etc.).
- Some types of electronic devices (frequency converters etc) can produce DC leakage currents. DC currents are not detected with AC current clamps!
- Only special current clamps declared as leakage clamps are suitable for this measurement.

Regulations

There is no special regulation for measuring leakage current in installations so far.

Documentation

For measurements at a certain test object, final test report is to be done, containing all parameters of the measurements like type of the measurement, type and serial number of the test instrument, test place etc. Measurement results must be placed into appropriate columns of the final test report.

Exercise No. 8-1: Leakage current measurement with current clamp – Demoboard MI 2067

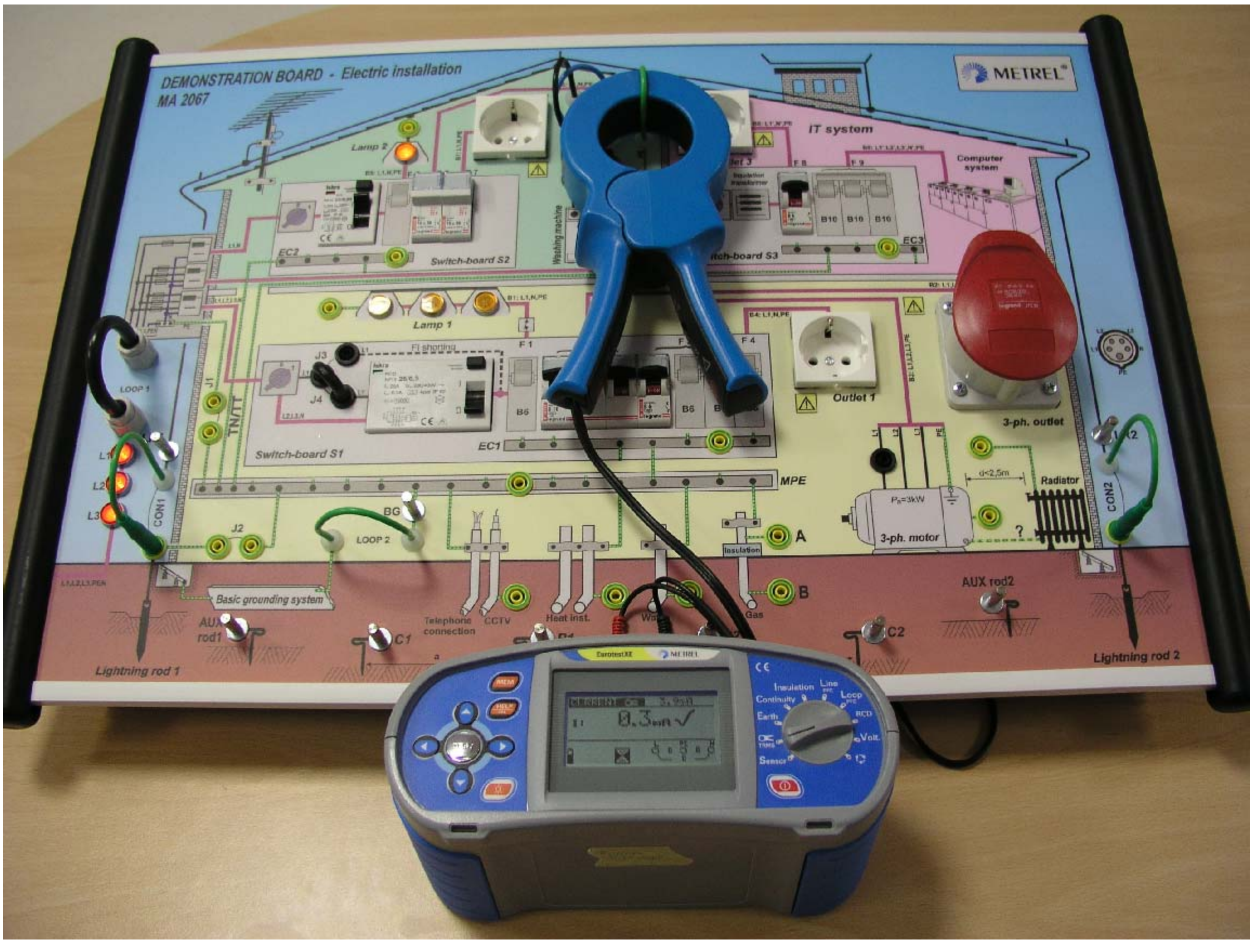
Simulation of faults with demoboard

Demonstration board has prepared several connections for current clamp measurements. In switch board S2 washing machine currents can be measured via three prepared loops. PE conductor current of washing machine can be increased with switch S8. The leakage current is too small to trip out the RCD in both cases.

Example with demoboard

The example shows the washing machine leakage current measurement.

Demoboard setup	*Condition*	*Notes*
S8 OFF	Appliance leakage ca xy Ω	Normal condition
S8 ON	Appliance leakage ca. 250 Ω	Appliance fault
Switch board 2: RCD, fuses ON		Mains voltage on


DEMONSTRATION BOARD - Electric installation
MA 2067
METREL
IT system
Lamp 2
Lamp 1
Switch-board S2
Switch-board S1
Outlet 1
3-ph. outlet
Radiator
3-ph. motor
MPE
Basic grounding system
Lightning rod 1
Lightning rod 2
AUX rod2
Telephone connection
CCTV
Heat inst.
Gas
Insulation
Computer system

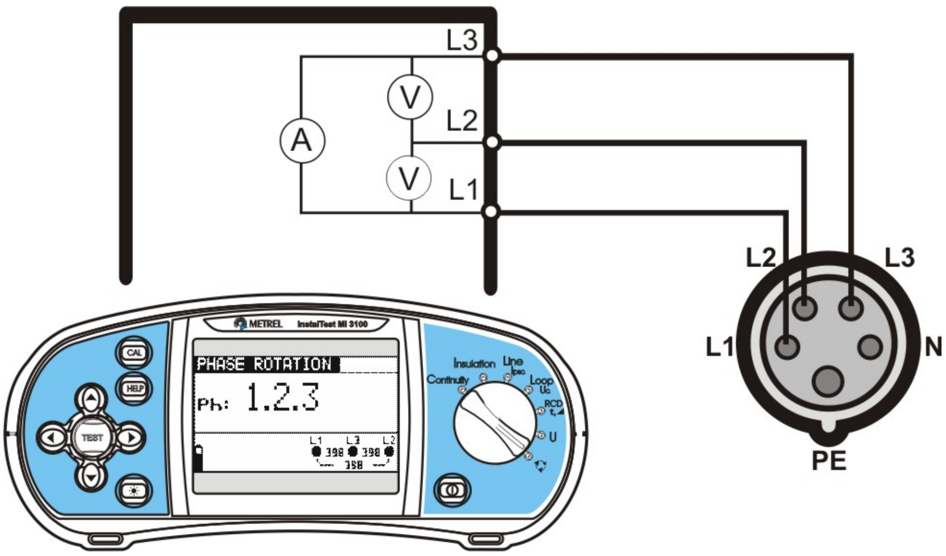
9. Phase rotation test

Background of measurement

In practice we often deal with the connection of three-phase loads (motors and other electro-mechanical machines) to three-phase mains installation. Some loads (ventilators, conveyors, motors, electro-mechanical machines, etc.) require an exact phase rotation and some may even be damaged if the rotation is reversed. This is why it is advisable to test phase rotation before connection is made.
The test instrument compares all three line-line voltages concerning amplitude and phase delay. Phase rotation is determined on that basis. If necessary, two line conductors must be exchanged between each other in order to reverse the phase rotation.

Exercise No. 9-1 Phase Rotation Test - general

Measuring connection



Measuring procedure

- Set VOLTAGE or ROTARY FIELD function.
- Connect item under test to instrument.

Notes:

- The instruments check the line-line voltages and phase delays between them. Result is correct if all three voltages are present, of approximately same size and in correct phase order.
- First, phase rotation on the reference mains outlet needs to be measured, where behavior of a specific machine (e.g. direction of phase rotation) is known. The direction should be noted.
- Measurement should to be repeated on an unknown mains outlet and both results compared. If necessary reverse the phase rotation.

Regulations
Specifications for rotary field measurements are defined in IEC/EN 61557-7.
General requirements for equipment for testing safety of electrical installation are defined in IEC/EN 61557-1.

Documentation
For measurements at a certain test object, final test report is to be done, containing all parameters of the measurements like type of the measurement, type and serial number of the test instrument, test place, operator etc. Measurement results must be placed into appropriate columns of the final test report.

Exercise No. 9-1 Phase Rotation Test – Demoboard MI 2067

Example with demoboard
Demonstration board, if connected to 3-phase mains system, enables measurement of 3-phase rotation at incorporated 3-phase outlet.